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Soil characterization, classification, and biomass accumulation in the Otter Creek Wilderness

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Soil Characterization, Classification, and Biomass Accumulation in the Otter Creek Wilderness

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ABSTRACT

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This study evaluated soils of the Otter Creek Wilderness in the Monongahela National Forest. Thirteen sites were sampled and analyzed according to landscape position: three terrace soils (T), four ridgetop soils (R), three sideslope soils with argillic horizons (SSA), and three sideslope soils with cambic horizons (SSC). AT each site, one pedon was described and sampled, and biomass data were collected. Standard chemical and physical properties, clay mineralogy, extractable sulfate and sulfated adsorption capacity were analyzed. The SSA soils had the highest pH, the most diverse vegetation, and the highest base saturation. These soils had a low ridk for acid toxicity to fine roots and mychorrizal fungi. Also, these soils has the highest Ca:Al ratio. In addition, SSA soils had the greatest capacity to adsorb additional sulfate. The most adverse soil conditions were found on the SSC and T sites, with R soils exhibiting moderate conditions.

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INTRODUCTION

Otter Creek Wilderness covers part of Tucker and Randolph Counties in West Virginia (Figure 1) and is found in a bowl formed by Shavers Mountain and McGowan Mountain. Many of the streams in this area drain into Otter Creek and then to the Dry Fork River. Vegetation consists of second-growth timber, rhododendron (*Rhododendron maximum)*, and a variety of mosses. Elevation ranges from 550 meters at the mouth of Otter Creek to 1190 meters on McGowan Mountain.

Figure 1. Otter Creek Wilderness in Tucker and Randolph Counties, West Virginia

Most of Otter Creek was obtained by the U.S. government in 1917 and was utilized predominately as a recreational area (Anonymous, 2001). Prior to this date, the area was logged by the Otter Creek Boom and Lumber Company from 1897 to 1914, and several areas also were homesteaded. When the lumbering operations ceased, the native trees came back naturally, with only some Norway spruce *(Picea abies)* planted on top of Shavers Mountain in the 1920's. More logging was done from 1968 to 1972 as the second-growth timber started to reach merchantable size. About this time, some persons began working to get the Otter Creek region set aside as a wilderness area. In 1975, the area was designated as wilderness by the Eastern Wilderness Act, passed by Congress that same year (Anonymous, 2001).

Researching and understanding forest soil characteristics and properties are essential to the long-term health and productivity of forested areas. Within the continental US, the hardwood forests of the east constitute the largest forest type (Adams et al., 2000) and are an important resource for millions of people, economically and for recreation. In depth evaluations of soil physical, chemical, mineralogical, and biomass properties gives foresters and others a greater understanding of the processes occurring in these forested environments and allows for better management practices.

This project was funded by the United States Forest Service (USFS) to update the characterization, classification, and mapping of soils in the Otter Creek Wilderness. The USFS employed the aid of the Natural Resources Conservation Service (NRCS) in conjunction with West Virginia University (WVU) to help meet their goals. The main interest of the USFS was to use the data generated from the soils of the Otter Creek Wilderness in air quality modeling. The objectives of this research were to

(1) characterize and classify major (previously unstudied) soils of the wilderness, and

(2) to evaluate biomass accumulation on the soils in the Otter Creek Wilderness.

LITERATURE REVIEW

General Properties of Forest Soils in Appalachia

Soil Temperature

Mean annual soil temperature (MAST) is a criterion used to classify soils at the family level (Soil Survey Staff, 1999). There are various ways to obtain this value. In the United States, an approximate estimate of MAST can be derived by adding $1^{o}C$ to the mean annual air temperature, but to obtain direct, more accurate measurements of MAST, once-a-month measurements of temperature at a depth of 50 cm below the soil surface is recommended (Buol et al., 1997).

One recent issue of interest in West Virginia and other areas of Appalachia is whether or not there are frigid soils in this region, and if so, at what elevations do they begin. A soil with a frigid soil temperature regime has a MAST of less than $8^{o}C$, whereas a mesic soil temperature regime has a MAST between 8 and $15^{o}C$ (Soil Survey Staff, 1999). In a study by Carter and Ciolkosz (1980), it was determined that there are parts of West Virginia that do indeed have frigid soils. They based this finding on a prediction

equation that was derived from seasonal readings at a 50 cm depth. The equation was dependent on elevation and latitude of the pedon site and was as follows:

$$Y = 11.7 - 0.0061X_1 - 0.0034X_2, \quad [1]$$

where relative latitude (distance from the equator in km) = X_1, elevation (m) = X_2, and Y = MAST. Using this equation, the mesic-frigid boundary was found to be 1,088 +/- 26 m at Davis, WV.

A similar study was conducted more recently where the authors focused on north facing aspects in Pocahontas and Greenbrier Counties, West Virginia (Mount and Paetzold, 2002). They formed an equation to determine the mesic/frigid break. This equation also used latitude and elevation as the determining criteria and was as follows:

$$Y = 46.204504 - 0.0023030202X \quad [2]$$

where Y = latitude in decimal degrees and X = elevation in feet. This equation produced a linear relationship relating latitude to elevation. If soil sites were above the line, they were considered frigid and if they fell below the linear relationship they were deemed mesic. The break for soils at 39^o latitude was approximately 969 m.

When comparing the two studies, the data generated from Mount and Paetzold (2002) indicated that frigid soils occurred at a slightly lower elevation than those from the Carter and Coilkosz (1980) report. This was probably due to the fact that the Mount and Paetzold (2002) study focused on north facing slopes where temperatures are generally

lower when compared to slopes with other aspects. For the most part, however, the two studies basically agreed on the dividing line between frigid and mesic soil temperature regimes.

Soil Organic Matter, Humus and Carbon

Organic matter (OM) is the nutrient rich media that accumulates on the forest floor, and in which the forest grows. It is an energy source for soil organisms which, through their activity and interactions with mineral matter, impart the structure to soil that affects its stability and its capacity to provide water, air, and nutrients to plant roots (Van Cleve and Powers, 1995). Soil organic matter (SOM) is a key parameter of soil quality and plays a role in aggregate stability, porosity, and the release and availability of soil nutrients (Schoenholtz et al., 2000). It is composed of living plant and animal tissue, detrital remains from these sources, exudates from plant root systems, products of microbial synthesis and leachates from above- and belowground organic sources (Van Cleve and Powers, 1995). The prolonged existence of mature forests leads to nutrient cycling processes that are near steady state, with hardly any natural disturbance from year to year, and an intact litter layer and SOM content that determine many of the physical, chemical and biological properties of the forest soil (McColl and Gressel, 1995).

This organic layer is a major source of humus in the mineral soil. Humus is composed of the recalcitrant products of decomposition and is chemically stabilized (Prescott et al., 2000). Compared to the original plant material, humus is low in carbohydrates, high in large polyphenolic molecules (lignin component), and high in N. However, most of the N is bound in complex molecules of undetermined composition,

and can be considered immobilized and essentially unavailable to plants and most microbes (Prescott et al., 2000). In acid forest soils, the humus fraction accounts for much of the soils' cation exchange capacity, as well as, aiding in soil structure development (Brady and Weil, 1999). Conversion of SOM to humus results in a distribution of very different kinds and qualities of soil organic carbon (SOC) throughout a pedon. Jenkins (2001) found that SOC generally decreased exponentially with depth with the average SOC stocks ranging from 11.3 to 18.8 kg m^{-2} for the West Virginia soils of his study.

One important aspect when examining the quality of a forested area is that although organic matter is undoubtedly beneficial to the system, one must consider that the substrate is at different levels of decomposition, and therefore, is at varying chemical and physical states, which in turn greatly affects the nutrient availability of the material. For example, Berg (2000) stated that in fresh litter, there may be a lack of macronutrients, such as N, P, and S thus limiting the decomposition rates of certain components, such as celluloses, and the rates may be positively related to, for example, the concentration of N. Berg further explained that with the disappearance of celluloses, the concentration of the recalcitrant compound, lignin, increases and the effects of N concentration of decomposition rates change completely. Another study demonstrated that while humus is a substantial proportion of nutrient capital of a site, is critical to long-term site fertility, and aids in buffering the site against disturbances that might lead to nutrient depletion, it is also viewed as a nutrient sink that essentially competes with the trees for the growth limiting resource (Prescott et al., 2000). Prescott et al. (2000) stated that this is especially true in the case of surface accumulations of agrading forests, where the progressive

immobilization of nutrients into humus may over time deplete the supply of available nutrients and reduce site productivity. These considerations need to be taken into account when attempting to manage a forested area.

One major characteristic of OM is its high concentration of C (compared to mineral soils). Forests dominate the terrestrial biosphere's C cycle, but many aspects of this cycle remain unresolved (Richter et al., 1995). Carbon, in forested situations, is found in living vegetation, in forest floor or the litter layer, and within the mineral soil. Because C storage is a net result of the processes of decomposition and primary production, controls of those processes, such as climate and soil properties, influence C storage (Grigal and Ohmann, 1992). The decay and storage of plant and animal remains in soil are basic biological processes and are fundamental parts of the C cycle. In the forest soil environment, respiration results in a release of CO_2 through roots and mycorrhizal fungi, from heterotrophs that utilize root exudates, and from heterotrophic catabolism of other SOM. During this process, C is recirculated to the atmosphere as carbon dioxide (CO_2) through respiration, and nitrogen (N) is made available as ammonium (NH_4^+) and nitrate (NO_3^-). Other related elements, mainly phosphorus (P), sulfur (S), and micronutrients such as iron (Fe), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and zinc (Zn), occur in forms essential for higher plants.

Bulk Density

Bulk density (Db) affects many physical aspects of soil including pore space, gas and water relations, infiltration rate, and rooting depth. Average bulk density of mineral soils ranges from 1.1 to 1.9 Mg m^{-3} with organic layers being considerably lower (Marshall et al., 1996). In an Appalachian forest, Jenkins found Db varying from 0.1 Mg m^{-3} in the O horizons to 2.06 Mg m^{-3} in the mineral horizons. Bulk density typically increases with depth of the soil pedon due to increasing overburden and decreasing disturbance (Marshall et al., 1996). Soil compaction will increase Db of a soil (Marshall et al., 1996), and this can be a detrimental effect of harvesting forests when using ground based logging equipment (McNabb et al., 2001). Compaction, hence elevating bulk density, can hinder productivity by increasing physiological stress in the seedling or tree, or in its competition with other vegetation (McNabb et al., 2001).

Soil pH

Soil pH is an important property of soils and impacts many soil processes. This property influences nutrient availability. It affects the chemical form, adsorption, and precipitation of these nutrients. In general, most forest soils are very acidic with soils under coniferous vegetation having a lower pH than soils forming under deciduous species (Ste-Marie and Pare, 1999). These soils become acidic through natural processes, such as mineral weathering, nitrification, and organic acid production, in addition to acidification through anthropogenic processes (i.e. acidic deposition). In fact, changing air quality has become a potential threat to the eastern hardwood forest ecosystem by altering soil acidity, and in turn, the nutrient balance of the soil (Adams et al., 2000).

Low pH soils have low base saturation and cation depletion associated with leaching and high aluminum concentrations, which can lead to aluminum toxicity in plants and other nutrient imbalances.

Cation Exchange Capacity and Exchangeable Base Cation Nutrients

Cation exchange sites in soil are either mineral (e.g., clays) or organic. This property is of concern because soils with low CEC values have a low buffering capacity and are susceptible to acidification and base cation leaching. Adams et al. (2000) rated soils as sensitive if they were poorly buffered with CEC values less than 15 $cmol_c/kg$, had moderate base saturation, and had a pH of less than 4.5. Spratt (1998) also confirmed that the principal mechanism for nutrient cation leaching in soils subjected to high levels of acidic precipitation was the exchange of nutrient cations, such as K^+, Ca^{+2}, and Mg^{+2}, for H^+ associated with SO_4^{-2} from the precipitation. Such cations are essential to long-term sustainability of forest ecosystems. In a forest quality report, McLaughlin and Percy (1999) noted that tree response and soil sensitivity to acidic deposition were closely related to soil supply capacity for basic cations. This sensitivity was particularly apparent in the northern Appalachians, where nutrient deficiencies of K^+ and Mg^{+2} were initially associated with sugar maple decline. The relationship between the decline and the soil sensitivity was supported by a response to K^+, Mg^{+2}, and Ca^{+2} fertilizer, which improved foliar nutrient status, growth rates, and tree vigor in the declining maples. In addition, Federer et al. (1989) concluded that long term depletion of base cations from both foliage and soils in the eastern U.S. has led to accelerated depletion of exchangeable cations from

mixed hardwood forested watersheds. Trettin et al. (1999) noted that deep rooting of trees was a major factor controlling cation uptake in mature forests. Therefore, it is often necessary to examine the pedon to depths greater than 50 or even 100 cm, the typical sampling depths. This was supported by the fact that although the upper 60 cm of the forest soils in their study showed cation losses, productivity was sustained, supposedly by deep soil pools.

Calcium and Aluminum

Calcium is essential to forest health and productivity, having a direct and indirect role in the allocation of resources related to defense and repair mechanisms in plants as well as affecting respiratory metabolism and transpiration rate (McLaughilin and Percy, 1999). Availability of calcium is important, especially in developing plants, because it is crucial in the structure and permeability of cell membranes, is essential for cell elongation and division, aids in the regulation of cation uptake, and is interrelated with N metabolism due to the enhancement of nitrate uptake (Halvin et al., 1999).

The natural acidifying processes of forest soils compounded with acidic deposition can reduce the availability of Ca^{+2} and create Ca^{+2} deficiencies, which can hinder productivity. When Ca^{+2} is leached out of the soil system due to a decline in pH, Al^{+3} increases, which can cause Al^{+3} toxicity and compound productivity threats posed by soil nutrient deficiencies (McLaughlin and Percy, 1999).

Many aspects affect the availability of Ca^{+2} and the rate at which Ca^{+2} is leached from the soil. Some soil factors that determine Ca^{+2} availability to plants include total Ca^{+2} supply, soil pH, CEC, percentage of Ca^{+2} saturation on CEC sites, type of soil

colloid, and the ratio of Ca^{+2} to other cations in solution (Halvin et al., 1999). Soil pH has an enormous affect on Ca^{+2} availability because as pH decreases, Ca^{+2} leaching increases. McLaughlin and Percy (1999) stated that acidic deposition is known to approximately double leaching rates that occur naturally. In a southeastern U.S. forest, Huntington et al. (2000) noted Ca^{+2} loses due to leaching to be approximately 2.7 kg ha^{-1} yr^{-1}, whereas in the more acid-polluted region of the northeast Federer et al. (1989) found Ca^{+2} to be leaching at a rate of 10 to 22 kg ha^{-1} yr^{-1}. Knoepp and Swank (1994) considered leaching to be the primary source of Ca^{+2} loss from the Ultisol soils in their study in the southern Appalachians. Trettin et al. (1999) also noted leaching as an important cause of Ca^{+2} loss from their upland-forested sites in Oak Ridge, Tennessee, but associated vegetation uptake as the major source of Ca^{+2} depletion. In addition to acidification increasing leaching, Trettin et al. (1999) found low-lying, depressional areas to have the greatest loss of soil Ca^{+2}. This was attributed to the low-lying areas functioning as a collection pont for water thereby increasing potential for leaching. Furthermore, tree species can affect Ca^{+2} depletion in a soil. Huntingtion et al. (2000) noted that hardwoods accumulate more Ca^{+2} than softwoods and that hardwood species dominated the sites with the highest net depletion rates and the lowest exchangeable Ca^{+2} inventories in the soil.

Calcium is replenished in the soil through mineral weathering, biocycling, and through atmospheric deposition. In the highly weathered soils often found in the old Appalachian mountains, the potential for replenishment for soil exchangeable Ca^{+2} is low. In a study conducted in Oak Ridge, Tennessee, Trettin et al. (1999), found that Ultisols and soils occurring on ridge-tops were highly weathered and were probably not

contributing much to the release of Ca^{+2} into the soil system. Generally, biocycling can maintain adequate nutrients for tree growth, but once biological cyclying is disrupted through forest harvesting, bases can be lost rapidly due to leaching (Huntington et al., 2000). Atmospheric deposition contributes to the Ca^{+2} supply of soil, however it only provides approximately 25% of the wood requirement for this cation, and this does not take into account leaching losses that occur once the cation is deposited (Huntington et al., 2000).

Many studies have shown that evaluating the molar Ca:Al ratio of soils is an important diagnostic tool for assessing forest soil stress due to high Al^{+3} concentrations (Cronan and Grigal, 1995; Lyon and Sharpe, 1999; Schoenholtz et al., 2000; Jenkins, 2001). Elevated Al^{+3} concentrations and an imbalance of Ca:Al in soil solutions can inhibit Ca^{+2} uptake, diminish fine root growth, disturb photosynthetic activity, and lead to nutrient imbalances in forest tree species (Lyon and Sharpe, 1999; Shoenholtz et al., 2000). If the Ca:Al ratio falls below 1.0, the risk of adverse effects on forest physiological functions increase (Cronan and Grigal, 1995). Cronan and Grigal (1995) established the following three stress risk levels related to Ca:Al ratios:

1. If the ratio was between 0.5 and 1, the soil was at a 50% risk level for producing Al^{+3} stress to trees,
2. If the ratio was between 0.2 and 0.5, the soil had a 75% chance for producing Al^{+3} stress to trees, and
3. If the ratio was less than 0.2, the soil was at a 95 to 100% risk level for generating Al^{+3} stress to vegetation.

Base Saturation

Base saturation (BS) indicates a relative level of base nutrient availability. When base saturation is low, Al is the dominant cation available for exchange and this could lead to reduced productivity due to aluminum toxicities and nutrient imbalances (Adams et al., 2000). In a review of chemical and physical properties of forest soils, Shoenholtz (2000) stated that in acid forest soils, base saturation was more important to the soils nutrient supplying power than CEC. Since soil acidification is a natural process in forest ecosystems, and since base cations are not routinely added, percent base saturation determines the influence of the exchange complex on soil solution chemistry and acidity.

In addition to being an indicator of aluminum toxicities and nutrient imbalances, base saturation also can be used as a guide for acid toxicity risks. In a study by Meiwes et al. (1986), threshold values of base saturation were established for the organic layer of forest soils to indicate the risk of acid toxicity to fine roots and mycorrhizal fungi. Three categories were established to represent these threshold levels as follows:

1. Little risk—BS values greater than 10% in the organic layer
2. Medium risk—BS values between 5 and 10% in the organic layer
3. High risk—BS values less than 5% in the organic layer.

By using these values as a guide, one can predict whether or not symbiotic fungi and fine roots are in danger of adverse effects from acid toxicity.

Sulfate and Sulfate Adsorption Capacity

Sulfate, the major form of inorganic S in forest soils, is derived from wet and dry deposition, mineral weathering, and catabolism of organic S (Mitchell et al., 1992). Sulfur may be retained by either geochemical or abiotic processes including adsorption and mineral formation or by the biochemical or biotic mechanisms of plant uptake and microbial immobilization.

Adsorption of SO_4^{-2} is generally considered to take place by two mechanisms: nonspecific adsorption where the anion is retained by electrostatic forces and secondly, by specific adsorption where the anion is bound covalently (Evangelou, 1998). The first adsorption mechanism results in an equivalent release of another anion, typically OH^-, especially in low pH soils (Fuller et al., 1985). This suggests an adsorption mechanism whereby the negative charge of SO_4^{-2} adsorbed onto an Al^{+3} or iron hydroxide surface is balanced by displacement of the OH^- ion (Mitchell et al., 1992; Fuller et al., 1985). The second term, specific adsorption, is used for all adsorption that cannot be entirely explained by electrostatic forces (Mitchell et al., 1992; Fuller et al., 1985).

Much research has focused on SO_4^{-2} retention and release in forested ecosystems, especially with respect to the affects of atmospheric deposition (Adams et al., 2000; Johnson et al., 1999; Spratt, 1998; Prenzel and Meiwes, 1994; Shaffer and Stevens, 1991; MacDonald and Hart, 1990; Harrison et al., 1989; Khanna et al., 1987; and Fuller et al., 1985). Through these and various other reports, it has become widely accepted that soils receiving increasing SO_4^{-2} via atmospheric deposition are in jeopardy of becoming SO_4^{-2} saturated. If deposition continues, soils will begin releasing SO_4^{-2}, as well as, H^+, Al^{+3} and beneficial nutrient cations into the groundwater system. This can cause an already

low pH soil to become more acidic with the potential for aluminum toxicity and nutrient deficiency.

It has also been determined, that net retention of SO_4^{-2} can potentially decrease the transport of potentially toxic H^+ and Al^{+3} to surface waters, and aid in retaining nutrient-rich, basic cations (Fuller et al., 1985; Harrison et al., 1989; Arbestain et al., 1999). Adsorption of SO_4^{-2} by soils is concentration dependent: soils will retain additional SO_4^{-2} as input levels of SO_4^{-2} increase up until SO_4^{-2} saturation, or steady state occurs (Adams et al., 2000). Sulfate saturation takes place when the soil is no longer accepting SO_4^{-2} onto soil adsorption sites at ambient precipitation levels (Adams et al., 2000). The reverse is also true. If the input concentration of SO_4^{-2} decreases and adsorption is reversible, decreased adsorption and increased SO_4^{-2} and cation leaching could result (Harrison et al., 1989). Johnson et al. (1999) observed reductions in soil solution SO_4^{-2} and Al^{+3} after a 50% reduction in N and S deposition. However, these soils were already SO_4^{-2} saturated and the reduction of SO_4^{-2} in solution was a direct result of the decreased S in the deposition. In soils still capable of retaining sulfate, the increase of soil solution SO_4^{-2} (and associated cations) is decreased over time until the soil becomes equilibrated with the input concentration of SO_4^{-2} (Harrison et al., 1989).

Inputs of S to the soil depend upon various environmental factors including atmospheric concentrations of SO_2, H_2SO_4 and neutral salts, seasonal variations, and the canopy and site characteristics of a forest stand (Khanna et al.,1987; Fuller et al., 1985). Site properties such as elevation and vegetation type affect atmospheric SO_4^{-2} loading rates (e.g. greater precipitation, cloud deposition, and less evapotranspiration at higher elevations) and as a result influence both SO_4^{-2} deposition and adsorption (Fuller et al.,

1985). Khanna et al. (1987) observed that forest soils in their study received higher inputs of S in winter months than in the summer months. They also noted that more atmospheric SO_4^{-2} was deposited at spruce *(Picea rubens)* sites than in beech *(Fagus grandifolia)* stands.

Adsorption and retention of SO_4^{-2} is dependant upon a multitude of soil characteristics, including soil pH (Adams et al., 2000; Prenzel and Meiwes, 1994; Mitchell et al., 1992), parent material (Arbestain et al., 1999), soil horizon type (Arbestain et al., 1999; MacDonald and Hart, 1990; Adams et al., 2000) organic carbon (MacDonald and Hart, 1990; Mitchell et al., 1992; Adams et al., 2000), Fe and Al oxides (Khanna et al., 1987; Mitchell et al., 1992; Adams et al.,2000) and percent clay (MacDonald and Hart, 1990; Mitchell et al., 1992; Adams et al., 2000). Obviously, there are many soil properties that affect the adsorption of SO_4^{-2}, hence making it difficult to pinpoint the exact reason why one soil may have a greater capacity than another to retain the anion. In addition, not all of the research is congruent, especially with how pH effects the adsorbing capability of the soil.

When soil is acidified, SO_4^{-2} adsorption will tend to increase (Arbestain et al., 1999; Mitchell et al., 1992). This is related to the increased positive surface charge that variable-charged soils acquire as pH decreases, thus increasing the retention of additional anions. When the pH of soils was artificially increased by liming, Prenzel and Miewes (1994) found that SO_4^{-2} in solution (leaching) increased. In addition, MacDonald and Hart (1990) established that soils having a higher pH had lower SO_4^{-2} adsorption. In contrast, however, SO_4^{-2} adsorption was higher in soils developing naturally from base-rich material having abundant Fe and Al oxy-hydroxides compared with that occurring in

soils developed from more acidic materials in the study by Arbestain et al. (1999). The reasons for this contrast were related to the actuality that there was not always a direct correlation between pH and SO_4^{-2} adsorption due to extraneous factors such as organic matter and parent material. Harrison et al. (1989) found a significant positive relationship between SO_4^{-2} adsorption and pH. And in still another study, Khanna et al. (1987) found that as pH decreased, SO_4^{-2} and Al^{+3} leaching increased. Some possible explanations to the apparent discrepancies among experiments could be due to differences in procedure. Also, Al and Fe oxides provide adsorption surfaces for SO_4^{-2}, and a low pH may result in solubilization of surface coatings of these oxides, thus destroying the Fe and Al adsorption site, ultimately reducing SO_4^{-2} retention (Mitchell et al., 1992; Harrison et al., 1987).

Organic C was found to be negatively correlated with SO_4^{-2} adsorption in a Michigan forest soil study (MacDonald and Hart, 1990). Fuller et al. (1985) also agreed that soils with higher accumulations of organic C adsorbed lower amounts of SO_4^{-2} and this phenomena was attributed to the organic matter actually blocking the anion adsorption sites. Mitchell et al. (1992) concurred, stating that organic matter was a competing ligand and may decrease SO_4^{-2} adsorption. Arbestain et al. (1999), however, found that organic C was not strongly correlated with the adsorption of SO_4^{-2}, but they did state that organic matter apparently had counteracting effects on SO_4^{-2} sorption. They attributed this to different counteracting mechanisms: (i) a negative mechanism, whereby dissolved organic C and SO_4^{-2} directly compete for sorption sites thus decreasing SO_4^{-2} sorption and (ii) positive mechanisms, whereby an increase in reactive surface is achieved by either stabilization of Al and Fe in Al- and Fe-humus complexes, or

association of minerals of low crystallinity with organic matter thus delaying the crystallization of Al and Fe oxides.

Most studies agree that there is a positive relationship between clay content and SO_4^{-2} adsorption capacity. MacDonald and Hart (1990) found that SO_4^{-2} adsorption capacity increased as clay percentage in forest soil increased. Adams et al. (2000) stated that soils sensitive to SO_4^{-2} saturation were those with relatively low clay content.

Amounts of Fe and Al in soils, especially extractable Al, appear to affect the retention of SO_4^{-2} in soils. As stated earlier, Fe and Al oxides provide surfaces for adsorption of SO_4^{-2} (Mitchell et al. 1992). Fuller et al. (1985), MacDonald and Hart (1990), and Arbestain et al. (1999) were in general agreement that there was a strong positive relationship between different extractable forms of Fe and Al occurring in soil and the SO_4^{-2} adsorption capacity of the soil. In the Harrison et al. (1989) study of forest soils, SO_4^{-2} adsorption by Inceptisols and Spodosols was most closely related to the concentration of oxalate extractable Al. Ultisols, however, did not appear to have a correlation with any of the Fe or Al extractions measured.

Sulfate adsorption capacity may vary by soil horizon. Arbestain et al. (1999) established that subsurface horizons tended to retain higher amounts of SO_4^{-2} than did surface horizons. This is probably most related to the decreased organic matter content in the lower horizons and increased clay content. MacDonald and Hart (1990) found that all A horizons and some E horizons of Michigan forest soils had a lower ability to adsorb SO_4^{-2} and were releasing the anion into the soil system. Again, the research suggested that this was attributable to high organic matter contents in the A horizons masking the

adsorption sites and the coarse-textured nature of the E horizons not being conducive to adsorption.

Biomass and Productivity

Biomass determination is an aid to management of forested ecosystems. It gives foresters and others an idea of the amount of material the forest is producing, as well as identifying problem areas where productivity is being hindered. Species, stand age, and stocking rate determine the amount of forest biomass on a site (Vitousek et al., 1988). Some factors affecting biomass and productivity include soil nutrient status (Frank et al., 1984; Hicks and Frank, 1984; Adams, et al., 2000; Huntington et al., 2000), organic matter content (Hicks and Frank, 1984; Jenkins, 2001), pH and acidification (Adams, et al., 2000), aspect --affecting soil temperature and moisture (Frank et al., 1984; Hicks and Frank, 1984), bulk density and soil compaction--affecting porosity, infiltration rate, hydraulic conductivity (McNabb et al., 2001), and slope and surface erosion (Grigal, 2000).

In a West Virginia study of a 50-yr-old hardwood forest (Frank et al., 1984), it was found that the following soil-site variables affected biomass: aspect, iron and copper in the B horizon, calcium in the A and B horizons, surface stoniness, and A horizon manganese, potassium and iron. Iron in the A and B horizons had a negative affect on total dry weight indicating possible iron toxicity, while copper and calcium in the B horizon had a positive relationship with biomass demonstrating deficiency possibilities

for these elements. Lime requirement, surprisingly, had a non-significant correlation to biomass, despite the relatively low pH of the soils in their study.

In this and similar studies, aspect has been shown to greatly affect biomass and productivity as well. Hicks and Frank (1984) stated that in general, south and west-facing slopes were the least productive and north and east facing slopes were the most productive. They found many factors to be associated with this phenomenon. Higher values, of Ca, K, Mn, and P were associated with north and east-facing slopes, while Fe, Al and H occurred in lower concentrations. The opposite was true for the less productive south and west-facing slopes. Also, soil moisture and accumulation of organic matter were related to aspect. Increased net radiation on south and southwest slopes elevated surface temperatures and drying of litter. The drier litter decomposed more slowly which provided less favorable conditions for soil vegetation and organisms, further slowing decomposition and increasing litter accumulation. The complex energy balance and soil nutrients on these aspects affected site vegetation and thus produced a less palatable litter for organic decomposition. The authors also recognized that particular trees were associated with certain aspects. They found, in general, that trees with leaves higher in lignin, such as various oaks *(Quercus L.)*, sassafras *(Sassafras albidum)* and cucumber *(Magnolia acuminata)*, were more often located on south and west-facing slopes, while trees associated with north and east aspects were more likely species such as red maple *(Aceraceae rubrum)*, yellow poplar *(Liriodendron tulipifera)*, hickory *(Carya L.)*, and black cherry *(Prunus serotina)*.

In recent years, forest soil nutrient status and its effects on biomass and productivity has been a major focus of research. Fertility of the soil environment affects

the amounts and kinds of biomass inputs (Jenkins, 2001). Nitrogen was historically believed to be the element most limiting to forest growth, but studies show that Ca^{+2} was more likely to be significantly depleted by harvesting and leaching, and this may threaten long-term sustainability of forest productivity (Huntington et al., 2000). Numerous studies have shown that many forest soils of today have an ample N supply from external source of anthropogenic processes (Rennenberg and Gressler, 1999; Garten, 2000; Ste-Marie and Pare, 1999; Huntington et al., 2000; McLaughlin and Percy, 1999; and Adams et al., 2000). However, Ca^{+2} has not been replenished by atmospheric deposition. Huntington et al. (2000) found atmospheric deposition to provide 75% of the estimated wood requirement for N, while only supplying approximately 25% of the wood need for Ca^{+2}. They also calculated that Ca^{+2} depletion would probably reduce soil reserves to less than the requirement for a merchantable forest stand in approximately 80 yr in the Peidmont forest of their study. In addition, the acid parent material that is often found in Appalachian forests will not provide much additional Ca^{+2} to developing soils (Jenkins, 2001). Other studies have shown that Ca^{+2} depletion was not a major concern and that harvest removals of Ca^{+2} were generally replaced within one rotation (Grigal, 2000; Johnson and Todd, 1998, and Knoepp and Swank, 1994). Obviously, the need for more research on the limiting nutrient status of forest soils is great and the uncertainties associated with the effects of nutrient removal on productivity need to be further evaluated.

There have been numerous reports on the various methods to determine forest biomass (Wharton and Griffith, 1998; Young et al., 1980; Wiant et al., 1979). Through these studies, equations were generated relating total dry biomass to stand volume, using

techniques based on diameter at breast height (DBH) and/or height of trees, seedlings and shrubs. In a West Virginia forest soil study, Jenkins (2001) found that out of all forest biomass inputs, sawtimber-sized trees (>12.7 cm DBH) comprised 79% to 92% of total site biomass. He also estimated total vegetative biomass for this Appalachian forest to range from 159 to 297 Mg ha^{-1}. Brown et al. (1999) reported similar biomass estimations for a West Virginian forest, with values varying from 180 to 220 Mg ha^{-1}.

METHODS AND MATERIALS

Site Description and Location of Soils

The research site is located in the Otter Creek Wilderness Area in the Cheat Ranger district of the Monongahela National Forest in Tucker and Randolph Counties, West Virginia (Figure 1). The area consists of various landforms occurring on a variety of geologic formations including the Conemaugh, Allegheny, Kanawha, and New River of Pennsylvanian age and the Mauch Chunk group from the Mississippian System (Figure 2). These formations are composed primarily of sandstone, shale, and mudstone with some zones containing limestone and siltstone. Elevation ranges from 550 m to 1190 m, so temperature can vary considerably, with the average daily maximum around 18^{o}C and the average daily minimum about 4^{o}C. The yearly precipitation average for this region is approximately 125 cm, and average relative humidity is high. The major vegetation in Otter Creek is Norway spruce (*Picea abies*), hemlock (*Tsuga conadensis*), yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharium*), red maple (*Acer*

rubrum), beech (*Fagus grandifolia*) and widely distributed rhododendron (rhododendron *spp*.) The major soils are alfisols, ultisols, inceptisols, and some spodosols (Losche and Beverage, 1967).

Thirteen sampling sites were chosen throughout the Otter Creek Wilderness by USDA Natural Resource Conservation Service (NRCS) soil scientists (Figure 2). The latitude and longitude of these sites are noted in the profile descriptions in Appendix A. These sites were sampled in August 1999 and 2000. They were selected to represent soils for which no previous data existed. These locations represented a range in soil mapping units, geologic formations and landscape positions.

Field Procedures

A soil pit was dug at each of the 13 sites (eight in 1999 and five in 2000) to a minimum depth of 99 cm with 11 of the 13 pits having depths exceeding 150 cm. All organic and mineral horizons were described by NRCS soil scientists according to cooperative soil survey guidelines (Soil Survey Staff, 1993). Most soils were described and sampled on the same day. Usually, vegetation, slope, and parent material were noted, as well as the longitude and latitude of the site. A large bulk sample was taken from each horizon and placed into a sampling bag for subsequent analyses. All samples were taken to West Virginia University where physical, chemical and mineralogical analyses were performed in the laboratories of the Division of Plant and Soil Sciences.

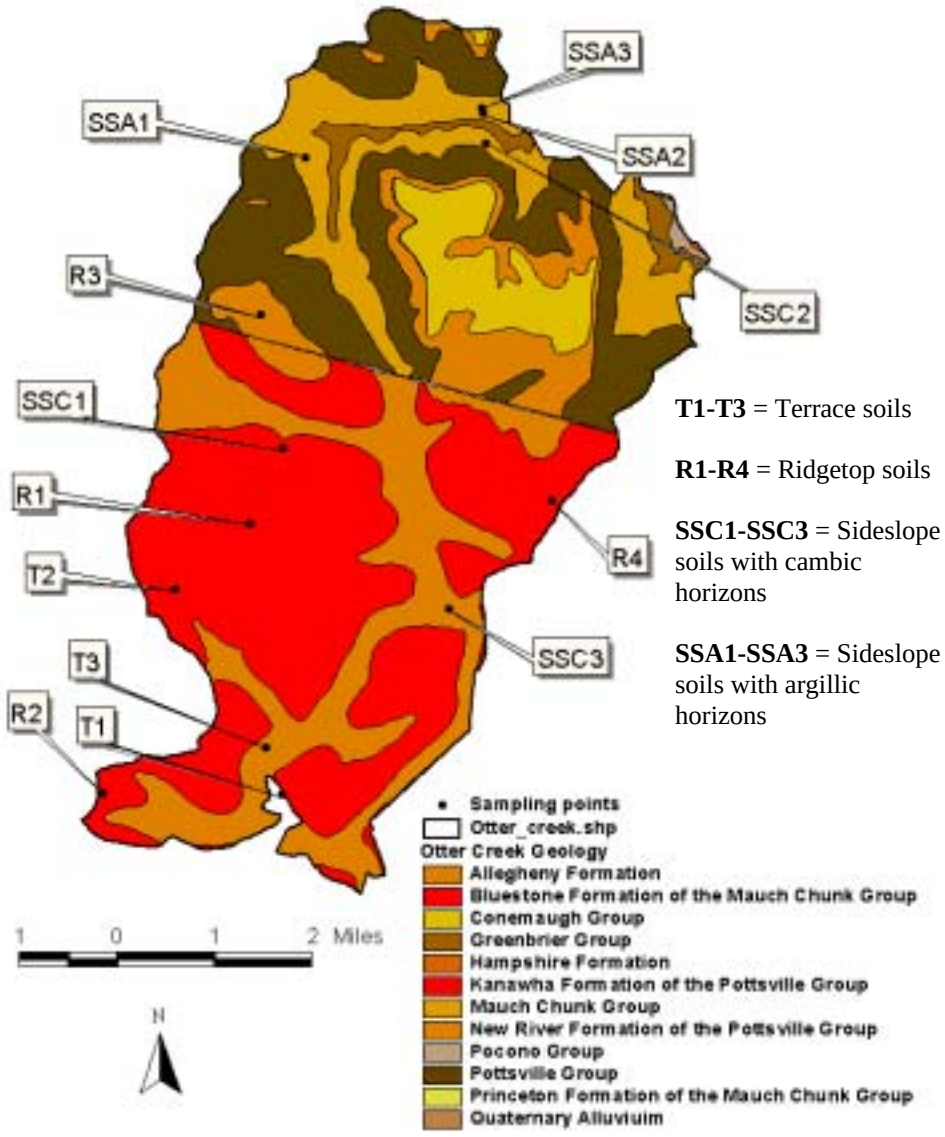

Figure 2. Geology of the Otter Creek Wilderness with soil pedon sites located.

Laboratory Analyses

Physical Properties

Each bulk sample was air dried and sieved to remove rock fragments from the fine earth fraction (<2 mm particle size diameter). The resulting rock fragments and soil components were weighed and rock fragment percentage, by weight, for each horizon was calculated. The soil sample of < 2 mm was then used for the remaining physical, chemical, and mineralogical analyses.

Two to four soil clods per horizon were used to determine total bulk density and bulk density <2 mm by the saran coated clod method (Soil Survey Staff, 1996). After the weight and volume of each clod were determined, the clods were broken apart and sieved for rock fragments. The corrected bulk density (<2mm) was then calculated.

In order to determine the bulk density of the organic horizons and some of the A horizons where clods could not be collected, a frame excavation method was used (Grossman and Reinsch, 2002). Again, rock fragments were removed and a corrected bulk density (<2 mm) for the horizons was established.

Texture was determined by the pipette method using 500-ml Fleakers (Indorante et al., 1990). Organic matter was removed using 3 % hydrogen peroxide with simultaneous heating to 80 ^{o}C on a hotplate. No treatments were utilized to remove carbonates from the soils due to low sample pH. It was assumed that little or no carbonates would be present. The sand portion of each sample was shaken through a nest of sieves at 500 oscillations per minute for 3 minutes. The openings of the sieves were 1.00 mm, 0.50 mm, 0.25 mm, 0.10 mm, and 0.05 mm, which separated very coarse, coarse, medium, fine, and very fine sands, respectively. One sample for each mineral

horizon was examined for particle size and a duplicate sample was run for one out of every four horizons.

Chemical Properties

Soil reaction (pH) was determined on a 1:1 water to soil suspension on all mineral horizons and a 2:1 to 8:1 water to soil suspension on all organic horizons depending on consistency (Method 8C1, Soil Survey Staff, 1996). Soil pH also was determined for a 2:1 $CaCl_2$ to soil suspension on all mineral horizons and a 4:1 to 16:1 $CaCl_2$ to soil suspension on the organic layers (Method 8C1e, Soil Survey Staff, 1996). A Fisher Scientific Accumet 915 pH meter was used to measure the pH in both methods.

Following the 1:1 pH measurements, additional distilled-deionized water was added to all mineral horizons creating a 2:1 water to soil solution. The organic soil horizons were freshly mixed to various ratios of water to soil, ranging from 3:1 to 12:1, again, depending on consistency. The mixtures were stirred, and electrical conductivity was determined by a Markson 4603 Solution Analyzer.

Total carbon, nitrogen, and sulfur were measured by combustion in a LECO CNS 2000 analyzer.

Average soil organic carbon (SOC) stocks were determined for each soil pedon. Calculations were made to 150 cm or to bedrock, whichever was shallower. Total pedon SOC stock (SOC_p) was calculated as the sum of the individual horizon SOC stocks (SOC_h) (Jenkins, 2001). Soil organic carbon for each horizon (SOC_h) was found using equation [3]:

$$SOC_h = \%C/100 \times Db \times H \times (1 - \%RF/100) \times 1000 \text{ kg/Mg} \quad [3]$$

where: SOC_h = Horizon SOC in kg m^{-2}; %C = percent organic carbon of oven-dry soil <2mm fraction; Db = bulk density (Mg m^{-3}); H = horizon thickness in m; %RF = volume percent rock fragments >2mm.

Extractable aluminum (Al) was determined using an automatic extractor and 1 *N* KCl as the extractant (Method 6G, Soil Survey Staff, 1996). Aluminum was determined by atomic absorption spectrophotometry on a Perkin Elmer AAnalyst 100.

The extractable acidity of the samples was released by using a barium chloride-triethanolamine ($BaCl_2$-TEA) solution buffered at pH 8.2 (Method 6H, Soil Survey Staff, 1996). The extracted solution was then titrated with 0.1 *N* HCl with the titration endpoint for the BaCl2-TEA set at pH 4.6. A Radiometer/ Copenhagen ABU93 Triburette titrator system was used.

Extractable calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}) were determined using the ammonium acetate (pH 7.0) with the automatic extractor method (Method 5A8, Soil Survey Staff, 1996). The cations Ca^{2+} and Mg^{2+} were measured on an inductively coupled plasma emission spectrophotometer (Perkin Elmer Plasma 400), and Na^{+} and K^{+} were analyzed on an atomic absorption spectrophotometer (Perkin Elmer AAnalyst 100). The addition of these bases plus $BaCl_2$-TEA acidity yielded cation exchange capacity (CEC) via summation. Cation exchange capacity also was determined on samples extracted by ammonioum acetate (pH 7.0) by steam distillation of ethanol washed samples on a Kjeldhal N analyzer (Method 5A8b, Soil Survey Staff, 1996). Percent base saturation (%BS) was calculated by multiplying the sum of the extractable bases by 100 and dividing by the CEC determined by summation.

Effective cation exchange capacity (ECEC) was determined by adding KCl extractable Al to the sum of the ammonium acetate extractable bases. Cation exchange capacity activity ratio was determined by dividing ammonium acetate CEC by percent clay. Apparent CEC was defined as ammonium acetate CEC per kilogram clay. This resulted in CEC being divided by the decimal of the total clay percentage.

The Bray P-1 method was used to determine extractable phosphorus (P) (Method 6S, Soil Survey Staff, 1996). Filtrates were analyzed on an inductively coupled plasma emission spectrophotometer.

Sulfate in each sample (20g) was extracted with 0.05 L of 0.0081 *M* $Ca(H_2PO_3)_2$ and analyzed on a Zellweger Analytics Lachat Quik Chem 8000. Extractable sulfate (SO_4) was determined turbidimetrically by flow injection analysis (Egan, 1998).

Sulfate adsorption capacity of the soils was found by equilibrating 10-g samples with 0.05 L of 0.312 mmol SO_4 L^{-1} in 0.01 *M* $CaCl_2$ (MacDonald and Hart, 1990). The samples were shaken for one hour on a wrist action shaker. Color (due to organic matter) removal by charcoal was insufficient. Color tainted solutions were corrected for impurities by running water blanks and subtracting the water value from the original read-out. A Zellweger Analytics Lachat Quik Chem 8000 was used for the analyses. Adsorbed sulfate was calculated from the disappearance of sulfate from solution.

Total elemental analysis was determined by total soil digestion using a combination of hydrofluoric, nitric, and boric acids (Soil Survey Staff, 1996). Modifications to the published procedure included substituting boric acid solution for solid boric acid. Also, a second digestion step was performed after the boric acid was added. The digestion was done in a CEM Mars5 microwave system and Al, Ca, Cu, Fe,

Mg, Mn, P, and Zn were determined on an inductively coupled plasma emission spectrophotometer. Sodium and K were measured on an atomic absorption spectrophotometer. Boron (B) could not be determined because of the procedure that was used. A Montana soil standard (reference number-2711) also was analyzed to ensure proper procedure for total elemental analysis.

Clay Mineralogy

Clay mineralogy of a major solum horizon from each pedon (13 in all) was determined by x-ray diffraction. A pretreatment of 30 % hydrogen peroxide was used to remove organic matter from each 5-g sample (Method 7A1b, Soil Survey Staff, 1996). Removal of carbonates was deemed unnecessary due to the low pH of the samples. Also, no care was taken to remove iron from the soils because of newer technology allowing for little or no iron interference (Renton, J., 2002, Professor of Geology, WVU, personal communication).

Each sample was dispersed with sodium hexametaphosphate and shaken overnight. Sands were removed by sieving through a 300-mesh sieve. The subsequent silt and clay suspension was collected and centrifuged at 750 rpm for 3 minutes. The clay was decanted and the silt discarded. The clay was separated into two samples and prepared for glass slides (Method 7A2a, Soil Survey Staff, 1996).

One clay sample (approx. 10mL clay solution) was saturated with $MgCl_2$ (1:1 clay suspenstion to $MgCl_2$) and the other sample saturated with KCl (1:1 clay suspension to KCl) (Bhumbla, D.K., Assistant Professor of Soil Science, WVU, personal communication). This initial step was done to flocculate the clays. The samples were

centrifuged and the supernatant was discarded. In a 50-ml centrifuge tube, about 40 ml of 1 *M* MgCl was added to the Mg-saturated samples and 40 ml of 1 *M* KCl was added to the K-saturated samples. The samples were vortexed to ensure that the respective ions made contact with all clay particles, and the clays were centrifuged around 1500rpm for 15 minutes. The supernatant was discarded and the clays were washed three or four times with distilled-deionized water. An eyedropper was used to collect a small clay sample and place it on a round glass slide. Each slide was subjected to x-ray diffraction.

The slides were then returned for further treatment. The Mg-saturated slides underwent glycerol solvation by being placed in a covered glass pan containing a layer of ethylene glycol. The slides rested on a raised mesh apparatus so that they were not lying directly in the glycerol. This treatment helps identify any montmorillonite in the clay sample. The K-saturated slides were heated in a muffle furnace at 550 ^{o}C for 4 hours. The heating process allows for chlorite identification.

Biomass Accumulation

At each site, above-ground biomass was sampled during the time of soil sampling. Biomass data for sawtimber, standing dead vegetation, sapling, seedling, and shrub layer were collected using criteria given in Table 1. These methods were developed by David Kingsbury (USDA-NRS), Robert Grossman (USDA-NRCS), and Linda Heath (USFS) (Biomass Sampling in the Northeastern United States. ND. National Survey Center, Lincoln, NE) as part of an unpublished protocol for carbon sequestration studies.

Table 1. Criteria used for biomass data collection at each pedon location.

Parameter	Criteria	Variables measured
Sawtimber	DBH > 12.7 cm	DBH, species
Standing dead vegetation	DBH > 12.7 cm	DBH, species
Saplings	2.5 cm < DBH <12.7 cm	DBH, species
Seedlings	0.25 cm < DBH < 2.5 cm	DBH, species
Seedlings	30 cm < height < 120 cm	Height, species
Shrubs	Non-tree species	Height, species

Diameter at breast height (DBH) was recorded at each site for sawtimber and dead trees within circular plots (0.08 ha). Trees with split trunks, at or below breast height, were accounted for by reducing the biomass estimates by 50% for all trunks except one (Jenkins, 2001). Five subplots were established 11.3 m from the sampled soil pedon. A 2.07-m radius subplot was used for all saplings with a DBH of 2.5 to 12.7 cm. A 1.13-m radius subplot was used for saplings of 0.25 to 2.5 cm, as well as all seedlings and shrubs, unless fewer than five individuals occurred, whereby the radius was increased to 2.07 m (Jenkins, 2001).

Allometric equations for approximation of whole tree biomass were used for estimating dry matter (Wharton and Griffith, 1998), including equations for saplings, seedlings, and shrubs as summarized by Young et al. (1980). Biomass was calculated using equation [4] for red maple, sugar maple, beech, red spruce, birch, and hemlock for sawtimber and saplings, 2.5 cm DBH and larger (Wharton and Griffith, 1998). For

yellow poplar, black cherry, and red oak, equation [5] was used. In each equation, b_0 and b_1 are species-specific coefficients. For these species, the equation only

$$\text{Ln } Y = b_0 + b_1 \text{ Ln (DBH)} \quad [4]$$

$$\text{Log } Y = \text{Log } b_0 + b_1 \text{ Log (DBH)} \quad [5]$$

estimates above-ground biomass and a factor of 1.23 was employed to predict whole-tree biomass (above-ground multiplied by 1.23). This is a weighted average based on the other hardwood species in the area as noticed by Jenkins (2001). Species-specific coefficients from Young et al. (1980) were used in equation [4] and [5] for saplings with DBH from 0.25 to 2.5 cm and seedlings from 0.3 to 1.22 m tall. Equation [6] was used for shrubs, where D was median stem diameter.

$$Y = b_0(D)^{b_1} \quad [6]$$

For species where no equation was published, an equation for a vegetative species most similar in density and growth habit was utilized. For basswood, the equation for yellow poplar was used, and the equation for sugar maple was used for ash. Trees that were dead were assumed to have lower densities than live trees, therefore the biomass estimates for these trees were reduced by 50% (Jenkins, 2001).

Rate of biomass accumulation at each site was determined by dividing the biomass data by approximate stand age (Appendix D). Stand age was determined from

information provided by the USFS (Appendix D). Information for every site was available, except for pedons SSA2 and SSA3. An average of all the stand ages were taken and used for these two pedons to determine their productivity (personal communication, Stephanie Connolly, USFS).

Statistical Analysis

Comparisons among soils were analyzed by Analysis of Variance (ANOVA) and means were separated by Duncan's Multiple Range Test. Chemical and physical properties of horizons within pedons, as well as, biomass accumulation were compared among four landscape positions: terrace (T), ridgetop (R), sideslope with cambic horizon (SSC), and sideslope with argillic horizon (SSA). Only those data that were significant at $p<0.05$ were reported.

RESULTS AND DISCUSSION

MORPHOLOGY, GENESIS, AND FIELD OBSERVATIONS

Terraces

There were three terrace soils sampled and described in this study (Appendix A). Each of these soils formed in alluvial/colluvial material from the New River and/or Kanawha sandstone (Fig. 2). The majority of the vegetation at these sites consisted of coniferous species, with some sites supporting yellow birch and red maple (Appendix D, Table 39). Elevations for these sites were fairly similar, varying from 957 m to 1030 m.

Each terrace location was nearly level to gently sloping, with slopes ranging from 2.5% to 5% (Table 2). All of these soils had more than 50% rock fragments somewhere within each pedon. The average mineral solum thickness (A and B horizons) was 89.5 cm (Table 2). All of these soils were very deep, each exceeding 150 cm in depth. Two were somewhat poorly drained (T1 and T2) and one was moderately well drained (T3).

Every terrace soil had an organic layer. Two soils had at least one layer of each of the three organic horizons (Oi, Oe, Oa), while the third soil (T3) only contained an Oi and Oe horizon. The thickness of these organic layers ranged from 11 to 15 cm (Table 2). Two of the three soils (T1 and T2) had E horizons and gleyed horizons, but T3 had neither one. All T soils had redoximorphic features, however, somewhere throughout the pedon. The two similar soils had sandier textures than the T3 soil.

Table 2. Average organic horizon thickness (O), mineral solum thickness (MS), slope, and drainage class of Otter Creek soils.

	Terrace	Ridgetop	Sideslope--Cambic	Sideslope--Argillic
O (cm)[1]	12.7	15	10.2	2.8
MS (cm)[1]	89.5	108	92.8	118.5
Slope (%)	4	3	50	51
Drainage Class[2]	SWPD	SWPD/PD	WD	WD

[1]O horizon and MS thicknesses were not significantly different at $p<0.05$
[2]WD = well drained, SWPD = somewhat poorly drained, PD = poorly drained.

All three soils were originally described as having cambic horizons, but after laboratory texture analysis, it was found that each of these soils had enough clay increase in the illuvial horizons to be considered argillic. The field soil scientist who described and sampled the pedons indicated that each of these soils had arguable clay films and

argillic horizons although they were border-line argillic. Also, these soils were developing in acidic Pottsville sandstone which has led to sandier soil textures (sandy loam, sandy clay loam). The lessivage process is not usually as active in soils with low weatherable mineral contents because there is less clay to move through the profile (Buol et al., 1997). These factors probably contributed to the difficulty in the clay film determination in the field.

Ridgetops

Four of the soils sampled in this study were located on the ridgetop positions (descriptions found in Appendix A). These soils developed in colluvium from Pottsville sandstone and shale. According to the geology map (Figure 2) site R3 formed in geologic material of the Allegheny Formation. However, the field soil scientist thought the soil formed from Pottsville geology, and he doubted that any Allegheny Formation material was present in this area.

It was initially assumed that these soils were forming in residuum, as one would expect on ridgetops. However, the field soil scientist believed that these ridgetops were very old land formations, whereby, through many years of weathering, the surrounding mountains had eroded away leaving what are now the high, flat ridgetops of colluvium that exist there today.

These soils had the highest elevations of any pedons in this study, ranging from 1110 m to 1190 m, with slopes of 1% to 4% (Table 2). The vegetation on these soils was mainly hardwood species, with some intermixed spruce, hemlock and rhododendron (Appendix D, Table 39). Each of these soils was deeper than 150 cm to bedrock and

were either somewhat poorly or poorly drained. Average mineral solum thickness was 108 cm (Table 2).

The organic layers varied greatly at these sites. All ridgetop soils had Oi horizons, two had an Oe, and three had at least one Oa. There was a wide range of organic matter thickness. Two of the soils had a 3-cm thick organic layer (R1 and R2), R4 had a 12-cm thick organic layer, and R3 had an organic layer that was 42 cm thick. Site R3 was covered with huge flags of sandstone and shale and was believed to have had frost-wedge/heave action from periglacial activity (Tony Jenkins, NRCS soil scientist, personal communication). Two sites contained E horizons (R3 and R4), while two did not (R1 and R2). Those soils with E horizons had O horizons above the E, but no A horizons.

Fragipans existed in all R soils. This is an unusual feature of ridgetop soils because generally, these soils form in residuum, and fragipans normally do not develop as readily in residual material as in other parent materials. However, as stated earlier, these are colluvial soils. The drainage classes (somewhat poorly drained) at these sites were indicative of soils with fragipans with the highest degree of fragipan expression (Ciolkosz, 1992). Redoximorphic features were found in every pedon and three of the four soils exhibited gleyed horizons. Gleyed prism faces are typical of soils with fragipans (Ciolkosz, 1992), as they act as an impeding layer, restricting water movement, and causing the “water table” to rise higher in the profile than it normally would without such a layer.

All ridgetop soils had cambic horizons except for R3. This soil was originally described in the field as having a cambic horizon, however, upon analyzing laboratory

texture data in conjunction with the mention of “few clay films” on the field report, it was decided that this pedon had an argillic horizon. Because of the sandy nature of the parent material, along with impeded water movement, it makes sense that most of these soils had cambic horizons.

A thin Bh horizon with spodic character was described in soils R4. This pedon was developing in the proper environment for such a layer to form. It had a sandy parent material, was very acidic, was supporting acid loving vegetation, had an established organic layer, and had a sandy loam/ loam texture throughout.

Sideslopes

For discussion purposes, the sideslope soils were divided into two categories: those with cambic horizons and those with argillic horizons. There were three pedons for each of the sideslope categories.

Sideslope-cambic

Sideslope soils with cambic horizons had various bedrock geologies (descriptions found in Appendix A). Two of the pedons were formed above Pottsville sandstone, one from the Kanawha Formation (SSC1) and the other from the New River Formation (SSC3) (Fig. 2). The third soil, SSC2, was located over Mauch Chunk geology (Fig. 2). All sites were located on extremely steep slopes, ranging from 38% to 68% (Table 2), and were developing in colluvium. The vegetation on these sites was deciduous, consisting mainly of beech, birch, and red maple (Table 39). Site SSC1 had very poor vegetation, but this was not unusual for the south-facing slopes of the area. The other

two sites had northeast aspects. Elevation varied considerably, with the lowest site around 670 m and the highest altitude at about 1010 m. Each site was well drained and had considerable rock fragment percentages throughout the profile. For these soils, the average mineral solum thickness was 92.8 cm (Table 2). Depth of these soils ranged from 99 cm where bedrock was hit to over 170 cm where bedrock was still not present (Appendix A).

All three pedons had organic layers. Two of the soils (SSC1 and SSC3) had well established organic horizons, containing Oi, Oe, and Oa layers, whereas the third soil (SSC2) only had Oi layers. This pedon (SSC2) was the steepest of the three and it also was forming on completely different geology, the Mauch Chuck. This lack of organic matter development was also noticed on the sideslope soils with argillic horizons, and they also were developing on the Mauch Chunk geology. Total thickness of the organic horizons ranged from 2.5 cm to 15 cm.

None of these soils included E horizons; however, pedon SSC1 had an A/E and a BE described. These sites were very steep which probably resulted in high run-off and little infiltration, not allowing for adequate flow through the profile to develop E horizons.

One pedon (SSC2) was initially designated as having an argillic horizon. It was determined, after examination of laboratory particle size data, that this soil did not have enough accumulation of clay in its illuvial layers to be considered argillic and was designated as having a cambic horizon.

Sideslope-argillic

Each of the sideslope soils with argillic horizons formed in colluvium from Mauch Chunk geology, which consists mainly of shale and mudstone. Like the sideslope cambic soils, these soils occur on very steep slopes, ranging from 44% to 59% (Table 2). These sites are supporting the most diverse vegetation, comprised mostly of hardwood, deciduous species (Appendix D, Table 39). The aspects varied from N to E to SW, while elevations ranged from 650 m to 847 m. Depth varied from 101 cm where bedrock was found to greater than 160 cm (and no bedrock) (Appendix A), with all sites being well drained. Average mineral solum thickness at these sites was 188.5 cm (Table 2). Rock fragments were found throughout the pedons, but compared to the other sideslope soils, the percentages were far less (20 to 30 % throughout).

There was very little organic horizon development at these sites, with no soil having more than an Oi horizon. These soils could have been truncated at some point due to a logging event, however, most logging that took place in Otter Creek occurred around the same time throughout the wilderness. The organic layers for these soils were all between 2 and 3 cm.

PHYSICAL, CHEMICAL, AND MINERALOGICAL PROPERTIES

Bulk Density

The bulk density (Db) of all soils in the study ranged from 0.1 Mg m^{-3} in the organic horizons to 1.9 Mg m^{-3} in the mineral horizons (Fig.3). Jenkins (2001) found similar results, with Db varying from 0.1 Mg m^{-3} in the O horizons to 2.06 Mg m^{-3} in the

mineral horizons. Generally, bulk density increased with depth, with average Db equaling 0.2 Mg m^{-3} in the O, 0.8 Mg m^{-3} in the A, 1.6 Mg m^{-3} in the B, and 1.7 Mg m^{-3} in the C horizon. Landscape position did not account for any apparent differences in Db, except for in B horizons. Bulk density for B horizons ranged from 1.2 Mg m^{-3} for soils occurring on SSC, 1.6 Mg m^{-3} for SSA and T soils, to 1.8 Mg m^{-3} for those soils located on the R position. The higher Db values for the R were attributed to the fragipan layer that was present in each of these soils. Statistical analyses indicated that R soils had significantly higher B horizon bulk density than the SSC soils, but there were no differences among any other horizons.

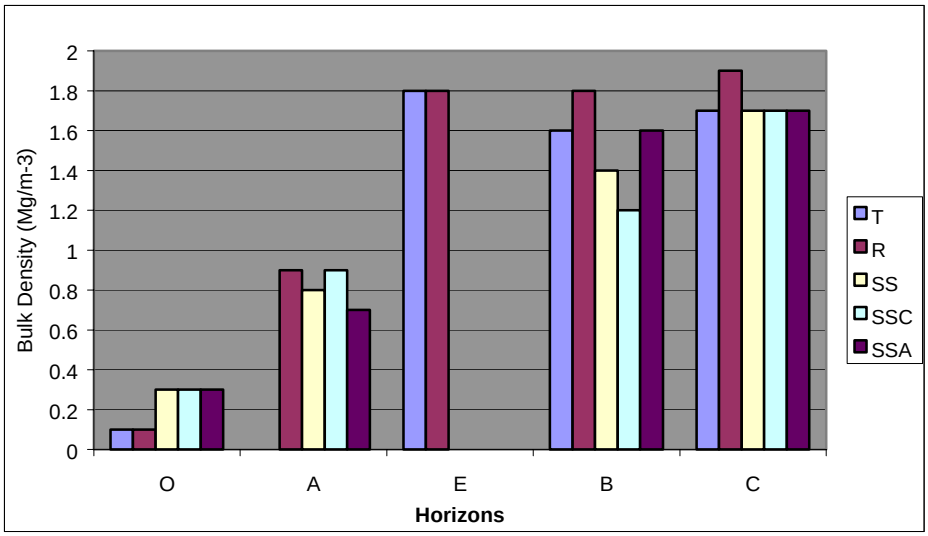

Figure 3. Average bulk density of Otter Creek soils on different landscape positions (missing data for Db for A horizon of T soils).

Percent clay

Clay contents increased from the A to the B horizon for R and SSA soils, and decreased slightly for T and SSC soils. All soils experienced a clay decrease from the B to the C horizon (Table 3) except R soils, which had a dramatic increase in clay from the

B to the C horizon. E horizons had the lowest clay content, as would be expected. Sideslope cambic soils had the lowest clay values and this was attributed to slope steepness and the geology not being conducive to clay generation.

Table 3. Clay percentages of soil horizons across landscape positions

Landscape Position	A	E	B	C
Terrace	22.9	9.5	22.2	20.2 ab[1]
Ridgetop	19.8	9.3	21.9	32.0 a
Sideslope	15.1	------	18.4	12.2 ab
Sideslope-Cambic	16.8	------	15.5	5.6 b
Sideslope-Argillic	13.5	------	21.4	18.9 ab

[1]C hroizon values followed by the same letter are not significantly different at $p<0.05$. Values for A and B horizons were not significantly different.

Percent Carbon

Soils in the Otter Creek Wilderness had typical carbon patterns, with carbon being the highest in the O horizons and steadily decreasing throughout the profile. Organic carbon values ranged from 38.1 to 44.5% in O horizons (Table 4). Data from Jenkins (2001) showed a wider variation in carbon values of O horizons in other soils from the same area with a low of 27.9 % and a high of 51.9 %. In the mineral horizons, carbon varied from 8.2% in an A horizon to 0.3% in a C horizon. These values were similar to the findings of Jenkins (2001). Ridgetop and T soils had higher carbon values in their A

horizons than did the SS soils. This was to be expected, considering R and T soils were wetter (poorly drained and somewhat poorly drained) than the SS soils (all well drained).

Table 4. Average percent carbon for horizons across landscape position for soils in the Otter Creek Wilderness.

Landscape Position	O	A	E	B	C
Terrace	39.6	8.1	0.9	1.0	0.6 ab[1]
Ridgetop	38.1	8.2	0.7	2.0	0.8 ab
Sideslope-Cambic	44.5	5.3	------	1.7	1.3 a
Sideslope-Argillic	38.3	6.1	------	0.8	0.3 b

[1]C hroizon values followed by same letter are not significantly different at $p<0.05$. Values for other horizons are not significantly different.

Soil organic carbon (SOC) stocks were similar to other soils in this region, and comparable to other forested soils throughout the U.S. When averaged among landscape position, SSA soils had the lowest SOC values at 13.5 kg m^{-2} and SSC soils were the highest at 20.4 kg m^{-2}, however no statistical differences were found between any of the landscape positions (Table 5).

Table 5. Carbon stocks for whole soils.

Landscape Position	Carbon (kg m^{-2})
Terrace	16.7 a[1]
Ridgetop	14.5 a
Sideslope-Cambic	20.4 a
Sideslope-Argillic	13.5 a

[1]Values followed by the same letter are not significantly differnet at $p<0.05$.

Jenkins' (2001) study showed SOC pools that varied from 11.3 to 18.8 kg m^{-2} for frigid spodosols and inceptisols, while SOC of mesic ultisols ranged from 8.9 to 11.7 kg m^{-2}. Although similar to my results, Jenkins values are slightly lower. Jenkins found that the method of determining bulk density greatly affected SOC results, with the generally practiced clod method overestimating bulk density, especially in upper horizons. In both Jenkins's study and this study, the frame method was used for all O and some A horizons, while the clod method was used for all other subsurface horizons. In a study of soils in the Lake States, Grigal and Ohman (1992) found C storage ranging from 13.9 kg m^{-2} in jack pine (*Pinus banksiana*) forested areas to 23.4 kg m^{-2} in regions occupied by hardwood species. They found that for mineral soils, areas with more precipitation and higher clay contents had greater C incorporation. These trends were not found in the soils of Otter Creek. They also considered tree species as a major factor in C sequestration, with deciduous trees having the highest SOC pools.

Soil pH

Average pH values for Otter Creek soils ranged from 3.3 to 5.6 (Fig. 4). It appears that SSA had slightly higher pH values than soils occurring on other landscapes. This was probably due to the formation of these soils on the Mauch Chunk geology and not the acidic Pottsville sandstone. The soil pH was reflected in the vegetation at these sites. Areas having higher pH values were producing hardwood species, whereas the most acidic soils, those occurring on the terraces supported more acid loving vegetation, such as hemlock, spruce, and rhododendron.

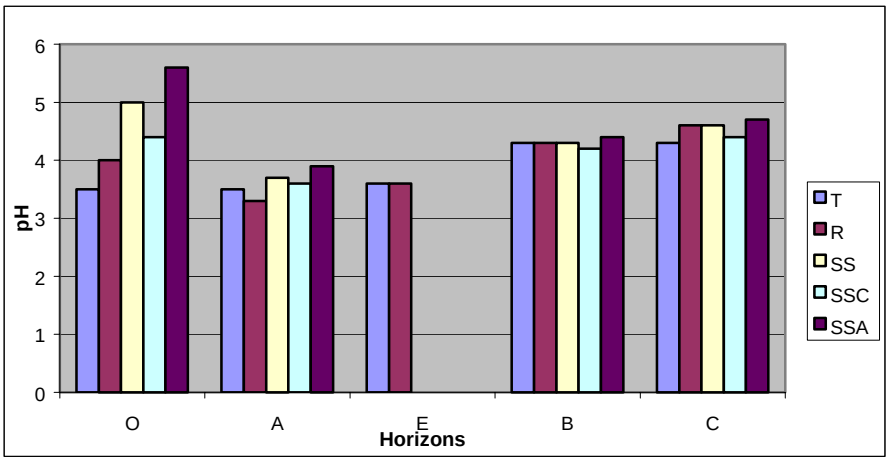

Figure 4. Average pH values of soil horizons in Otter Creek across various landscapes.

Calcium and Aluminum

Determining calcium and aluminum in forest soils is important because of the general acidic nature of these soil ecosystems. In conjunction with the natural acidifying processes of forest soils, acidic deposition can increase leaching of Ca^{+2} and thereby reduce its availability. Calcium deficiencies can become prevalent which can ultimately be detrimental to productivity. In tandem with this reduction in calcium, Al increases, which can cause Al toxicity and compound productivity threats posed by soil nutrient deficiencies (Huntington, 2000; Lyon and Sharpe, 1999).

Overall, terrace soils were found to have the lowest exchangeable Ca concentrations (Fig. 5). These soils were the most acidic and had the lowest percent base saturation. This agreed with work done by Adams et al. (2000) where they stated that soils most sensitive to a decline in forest productivity due to base cation depletion were those developing on acidic parent material with low percent base saturation and pH values less than 4.5. The SSA soils on the other hand had the highest exchangeable

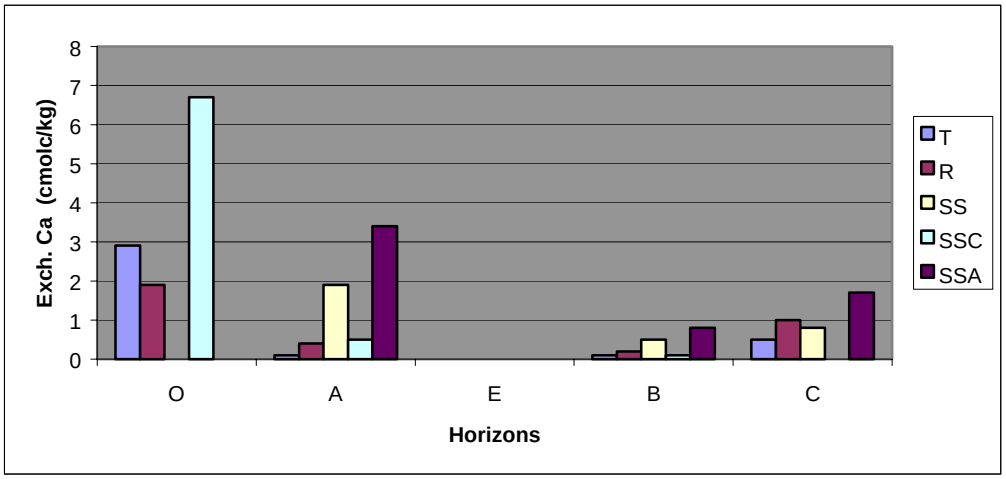

Figure 5. Average exchangeable calcium concentrations of forest soil horizons in the Otter Creek Wilderness.

calcium concentrations (Fig. 5) and developed on less acidic parent material and had the highest percent base saturation.

For all soils in this study, average exchangeable Ca ranged from trace amounts in the E horizons to 6.7 $cmol_c$/kg in the SSC organic layer (Fig 5). Among the various horizons, the organic and A horizons had the overall highest concentrations of calcium (averaging 3.8 $cmol_c$/kg and 1.1 $cmol_c$/kg, respectively). This was attributed to biocycling of the organic matter, in addition to the calcium that was stored in the organic horizons being leached more slowly than in the mineral horizons (Lyon and Sharpe, 1999). In a Pennsylvania forest soil study, Lyon and Sharpe (1999) recognized that the relatively high Ca levels noticed in O horizons was attributed to the decomposition of litter that had a relatively high Ca content. The lowest average Ca values were found in the E and B horizons (trace levels and 0.3 $cmol_c$/kg, respectively) because of a decrease in organic matter in conjunction with these horizons being more highly weathered. Huntington et al. (2000) also reported higher exchangeable Ca values in the A horizons of their

Piedmont forest soils compared with the B and E layers, with the E horizons having the lowest concentrations. Calcium content in their soils ranged from 0.22 $cmol_c$/kg in the E horizons to 3.2 $cmol_c$/kg in the A horizons. These values were slightly higher than the concentrations that were found in the Otter Creek soils. The higher Ca observed in the Piedmont study could be a consequence of the liming during the period of cultivation prior to afforestation. There was an increase of Ca in the C horizons (average of 0.8 $cmol_c$/kg) of the Otter Creek soils, probably due to the less weathered nature of this layer having reserves of weatherable minerals that could supply Ca to the soil. In a similar study, Jenkins (2001) noted that exchangeable Ca decreased with depth and did not increase in the substrata.

In general, extractable Al was highest in the A horizons (average of 8.7 $cmol_c$/kg) for all soils and lowest in the O and E horizons (average of 2.4 $cmol_c$/kg and 1.0 $cmol_c$/kg, respectively) (Fig. 6). Lyon and Sharpe (1999) also reported their organic horizons contained the lowest levels of extractable Al when compared to other horizons. This was expected because Al is typically complexed with organic compounds in solution and solid phase organic matter has the compacity to complex both monomeric and polymeric Al, making Al, for the most part, unavailable as an exchangeable ion (Lyon and Sharpe, 1999). Trettin et al. (1999) found that Al concentration was higher in the B horizons than the A horizons in Tennessee forest soils. This would be expected if relating Al concentration to a decrease in organic matter (more Al is available because there is less organic matter to retain it), however, soils in this study had higher Al levels in the A horizons (average of 8.7 $cmol_c$/kg) compared with the B (average of 5.3 $cmol_c$/kg). Furthermore, pH values were less in the A horizons than in the B horizons

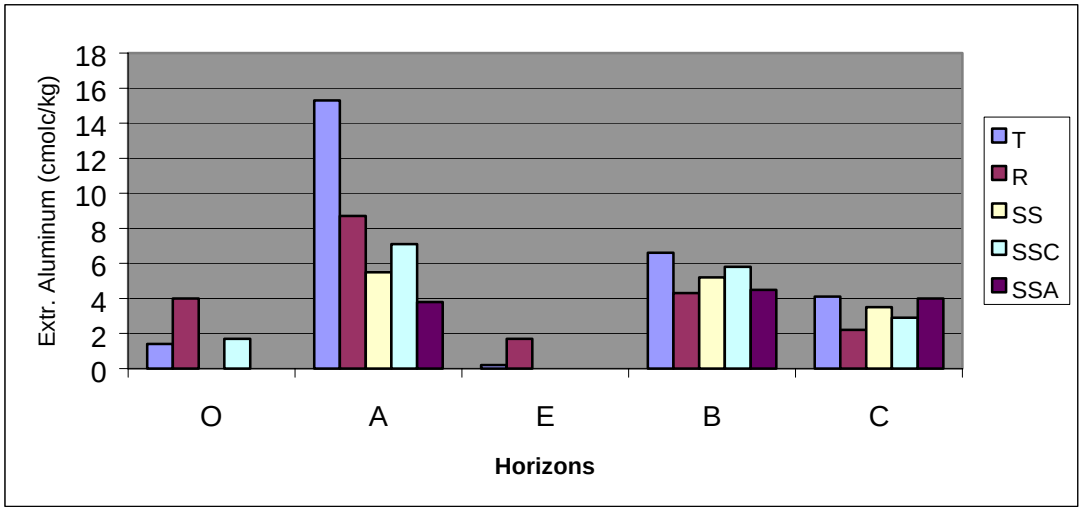

Figure 6. Extractable aluminum of forest soil horizons in Otter Creek across various landscape positions.

(Fig. 4), and as pH decreased, Al increased and adsorption of Al to clay surfaces will decrease CEC.

Molar Ca:Al ratios have been suggested as an indicator of potential nutritional stress because of the damaging effects of escalated Al levels on root proliferation and on base cation uptake and nutrition (primarily Ca) (Cronan and Grigal, 1995; Lyon and Sharpe, 1999; Jenkins, 2000; Schoenholtz et al., 2000). Cronan and Grigal (1995) established that if the molar Ca:Al ratio fell below 1, then there was potential for adverse effects to forest physiological functions. They were even more specific and developed further risk of Al stress criteria based on the value of the Ca:Al ratio in soil solution: < 1 (50% risk): < 0.5 (75% risk): and < 0.2 (95-100% risk). This ratio was calculated for the Otter Creek soils across the various landscape positions and is represented in Figure 7. All soils fell below the initial threshold of 1, indicating that every soil in this study was at risk for possible detrimental effects due to Al toxicity. The SSA soils were the only ones

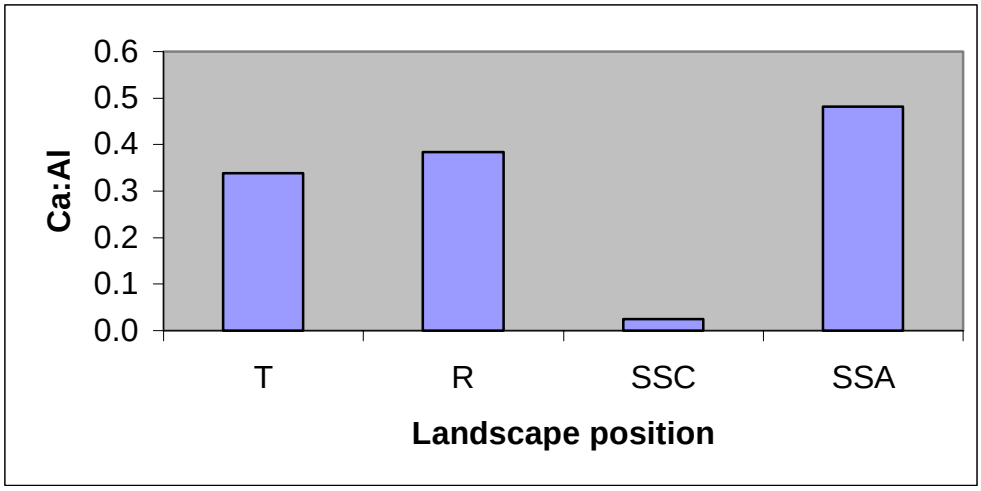

Figure 7. Ca:Al molar ratio of Otter Creek soils spanning different landscape positions.

in the 50% risk category, T and R soils were at a 75% risk, while SSC soils were at a 95-100% risk of adverse effects from an imbalance of Ca and Al.

Cation Exchange Capacity

Cation exchange capacity (CEC) via summation was generally slightly higher than the ammonium acetate-Kjeldhal method, but trends were similar (Table 6). Since the summation method was used for classification, it was chosen to represent the CEC values for comparison purposes. This property is of concern because soils with low CEC values are susceptible to acidification and base cation leaching and indicate that the soil has a low buffering capacity. Cation exchange capacity decreased throughout the profile, with the highest values appearing in the organic layers, followed by the A horizons (Fig. 8). Landscape position did not appear to make any difference in the cation exchange capacity of the soils. Average CEC values ranged from 7.2 $cmol_c$/kg in the highly weathered E horizons to 113 $cmol_c$/kg in the nutrient-rich organic layers (Fig. 8).

Table 6. Cation exchange capacity (CEC) and effective cation exchange capacity (ECEC) of horizons across landscape positions.

Horizon		T	R	SS	SSC	SSA
		----------$cmol_c\ kg^{-1}$----------				
O	CEC (sum)	113.0	72.1	103.5	103.5	N/A
	CEC (pH 7)	94.8	60.1	109.3	109.3	N/A
	ECEC	5.6	6.7	9.9	9.9	N/A
A	CEC (sum)	50.0	39.1	27.6	25.3	29.9
	CEC (pH 7)	36.3	68.9	23.0	22.5	23.5
	ECEC	15.7	9.5	8.0	7.8	8.2
E	CEC (sum)	13.0	7.2	N/A	N/A	N/A
	CEC (pH 7)	8.2	4.5	N/A	N/A	N/A
	ECEC	4.2	1.7	N/A	N/A	N/A
B	CEC (sum)	18.7	15.0	17.1	20.3	13.9
	CEC (pH 7)	12.0	11.3	14.0	17.7	10.3
	ECEC	6.9	4.7	5.9	5.9	5.9
C	CEC (sum)	12.7	10.7	12.3	11.9	12.6
	CEC (pH 7)	8.0	8.5	9.3	8.2	10.3
	ECEC	5.0	4.3	5.0	2.9	7.0

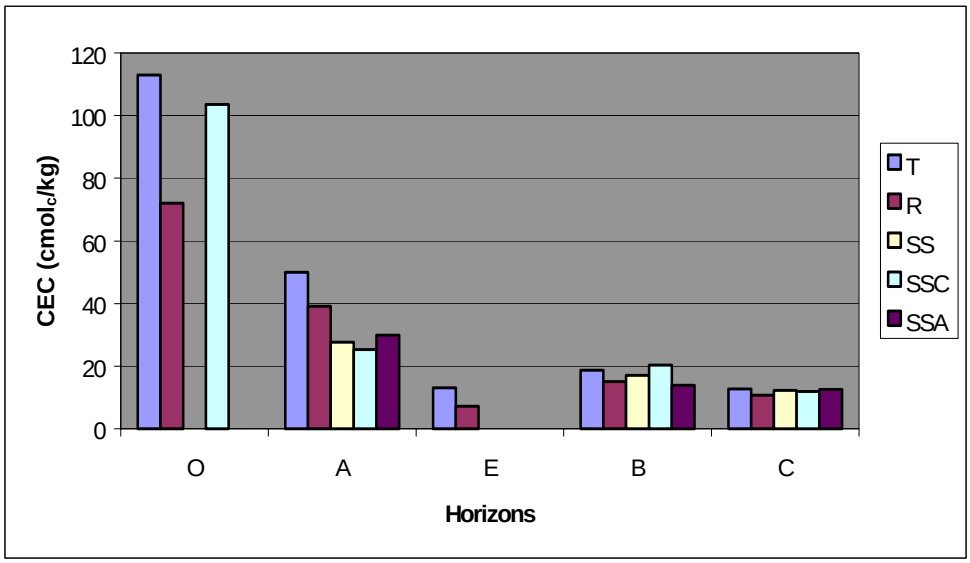

Figure 8. Cation exchange capacity (via summation) of soils in the Otter Creek Wilderness

Effective cation exchange capacity (ECEC) also was calculated for the soils of Otter Creek (Table 6) and followed the pattern of CEC, decreasing with depth throughout the mineral solum (excluding E horizons, which had the lowest ECEC values), however, ECEC increased slightly in the C horizon of SSA soils. Across landscape positions, ECEC was highest in T soils (average 7.5 $cmol_c\ kg^{-1}$) and lowest in R soils (5.4 $cmol_c\ kg^{-1}$). The higher value for the T soils was attributed to escalated Al in the A horizon giving rise to higher ECEC.

Base Saturation

Base saturation of SSA soils A+E horizons was significantly higher ($p<0.05$) than base saturation of A+E horizons on other landscape positions. There were no significant differences among landscape positions for any other horizons. Base saturation for SSC and T soils were very low, with the average BS within the major mineral horizons being less than 2% and 4%, respectively (Fig. 9). This was probably due to these soils having the highest extractable acidity and Al (Fig. 6) values, as well as, the lowest exchangeable Ca concentrations (Fig 5). The SSA soils had the highest BS, with the average among the mineral horizons being 15.8 %. The higher values in these soils were attributed to the parent material for these pedons. The Mauch Chunk geology produced clay-rich soils capable of retaining the cations giving rise to higher base saturation levels. Ridgetop had an average of 6.7 % BS throughout the mineral layers. E horizons for R soils had only a trace amount of extractable bases, therefore, %BS was negligible.

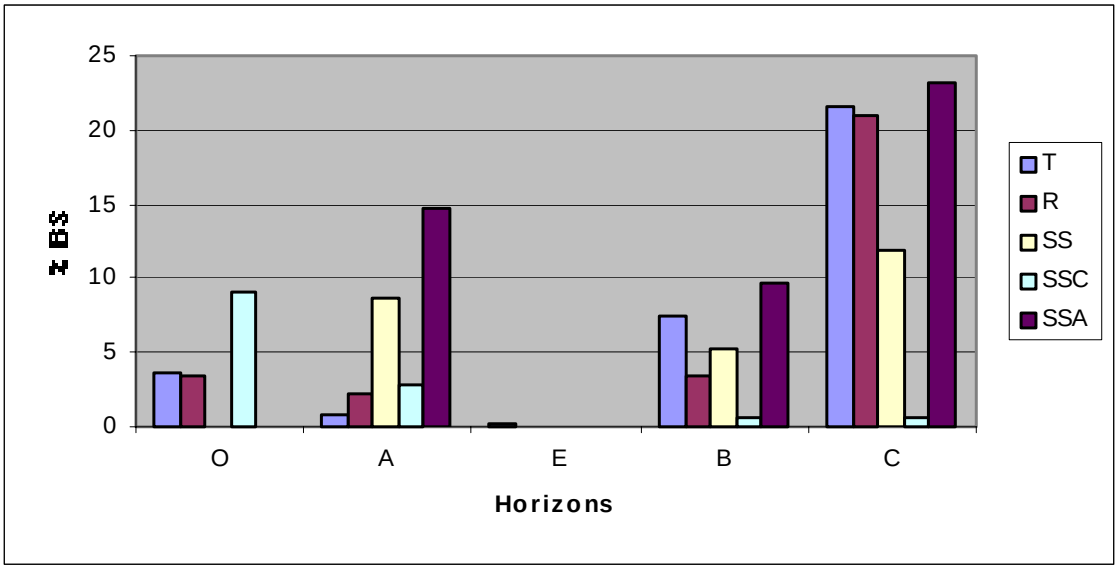

Figure 9. Average percent base saturation of horizons for Otter Creek soils across different landscape positions.

In addition to BS acting as a relative indicator of nutrient status in acid soils, it may also indicate acid toxicity risks to fine roots and mycorrhizal fungi in the organic layers of forest soils. Meiwes et al. (1986) developed three threshold levels to indicate these risks. They were: high (BS<5%), medium (BS between 5-10%), and low (BS>10%) in the organic horizons. No soils were in the low risk group. Figure 9 shows that only organic horizons of SSC soils were in the medium risk category, while T and R soils were both at a high risk for damaging fine roots and mychorrizal fungi due to acid toxicity. The SSA soils had no organic horizons except Oi's which were not analyzed.

Another assessment of whether a soil was at risk of potential Al stress and/or acid soil infertility involved determining the base saturation of the effective cation exchange capacity (BSECEC). Cronan and Grigal (1995) proposed that if the BSECEC was less than 15%, then the soil would be at risk for Al toxicity and acid soil infertility. In the

mineral solum, all soils in this study were below this threshold, except for argillic soils occurring on sideslopes (Table 7). This was due to the SSA soils having a greater supply of exchangeable bases on their exchange sites. In a similar study in the same forested region, it was found that for most pedons, the BSECEC dropped below 15% within 20 cm of the surface (Jenkins, 2001). According to this indicator, all soils (excluding SSA soils) were in jeopardy of potential forest productivity decline.

Table 7. Percent base saturation of the effective cation exchange capacity of the mineral solum of soils across various landscape positions.

Landscape Position	BSECEC (%)
Terrace	5.9
Ridgetop	12.0
Sideslope—Cambic	6.4
Sideslope--Argillic	35.6

Clay Mineralogy

X-ray diffraction offers semiquantitative estimates, but is a useful method to identify the crystalline mineral components of the soil (Soil Survey Staff, 1996). It was decided to report clay mineralogy with respect to geology (Table 8) and not landscape position because of the strong influence geology has on the clay species found in the soil. The different geologies identified in this study include the New River and Kanawha Formations of the Pottsville group and the Mauch Chunk group. It needs to be noted that

although the New River and Kanawha formations are part of the Pottsville group, some of Otter Creek was mapped simply as Pottsville with no formation associated with it, as was the case with pedon R3. It should also be pointed out that this was the same soil that was designated as the Allegheny Formation, however, as stated earlier, this geology is unlikely present in the area.

Individual data noting landscape position, horizon, and geology can be located in appendix E. Pedon SSC3, developing from the New River Formation, was not calculated into the averages because many of the clay species occurred as mixed-layer minerals, whereby the individual clay minerals were unidentifiable. This led to skewed percentages for those minerals that were recognized. Information for this soil can also be found in appendix E. The Pottsville category contained only one soil (R3) and therefore does not have an associated range.

Table 8. Average percentages and ranges of clay species found in Otter Creek soils with respect to geology.

		n	V	K	I	L	Q
			----------%----------				
New River	ave	2	50	28	2	11	10
	range		47-53	20-35	0-4	8-14	10-10
Kanawha	ave	5	29	26	9	10	25
	range		0-52	18-41	6-18	0-22	11-48
Pottsville		1	A	35	22	11	29
Mauch Chunk	ave	4	42	23	10	A	26
	range		35-51	21-26	8-14	A	20-30

n= number of samples, V= Vermiculite, K= Kaolinite, I= Illite, L= Lepidocrocite, Q= Quartz, and A= Absent.

Montmorillonite and chlorite were not detected in any of the soils. Vermiculite was found in the greatest abundance in all samples except for the Pottsville category

where it was not detected (Table 8). This was similar to findings from Feldman et al. (1991) where vermiculite was found to dominate the clay fraction on the high elevation forest soils of the southern Appalachians. Kaolinite was the second most prevalent clay species. Illite was found in relatively small quantities in all samples, except for the Pottsville class where it made up 22% of the total clay mineralogy. Lepidocrocite, not actually a clay mineral, but an iron oxy hydroxide (FeO(OH)), was present in all samples except for soils occurring on the Mauch Chunk geology. For the New River and Kanawha soils, this mineral was more prevalent than illite. The presence of lepidocrocite in the T and R soils, and not the SS soils was probably due to the wetness of the T and R soils and not the geology. Schwertman (1988) found that high chroma mottled areas found in wet soils are composed primarily of the mineral lepidocrocite. Quartz dominated approximately 27% of the total clay fraction of all samples, excluding the New River geology, where it occupied only 10%.

CLASSIFICATION

All pedons of this study were characterized and classified to the family level (Table 9)(Soil Survey Staff, 1999). There were three soil orders recognized: 6 Inceptisols, 6 Ultisols, and one Alfisol. All data used for classification of these soils may be found in appendices A, B, and C.

Table 9. Soil Classifications

Terraces
- **T1**~Loamy-skeletal, mixed, active, mesic Typic Endoaquults
- **T2**~Loamy-skeletal, mixed, active, mesic Typic Endoaquults
- **T3**~Fine, mixed, active, mesic Aquic Haplohumults

Ridge-tops
- **R1**~Fine-loamy, mixed, superactive, frigid Aeric Fragiaquepts
- **R2**~Fine-loamy, mixed, semiactive, frigid Aquic Fragiudepts
- **R3**~Loamy-skeletal, mixed active, frigid Aquic Fragiudults
- **R4**~Loamy-skeletal, mixed, superactive, frigid Aeric Fragiaquepts

Sideslope-Cambic
- **SSC1**~Loamy-skeletal, mixed, superactive, mesic Typic Fragiudepts
- **SSC2**~Loamy-skeletal, mixed, superactive, mesic Humic Dystrudepts
- **SSC3**~Loamy-skeletal, mixed, superactive, mesic Typic Dystrudepts

Sideslope-Argillic
- **SSA1**~Fine-loamy, mixed, active, mesic Ultic Hapludalfs
- **SSA2**~Fine-silty, mixed, superactive, mesic Typic Hapludults
- **SSA3**~Fine-silty, mixed, active, mesic Typic Hapludults

Terrace soils

Soil Order

There were three soils occurring on the terrace/high floodplain landscape. Each soil was described in the field as having cambic horizons (Bg's or Bw's), however, laboratory data (Appendix B) show that each pedon had enough clay increase from the eluvial layer to the illuvial layer (in this case, greater than 1.2 times) for these horizons to be considered argillic. Field soil scientists mentioned "some arguable clay films observed" on the field description sheets, so these soils were considered to have Bt horizons (instead of Bw's) and were therefore classified accordingly (note: the profile

descriptions in Appendix A reflect what the field soil scientists reported in the field and not what laboratory data and subsequent discussion with these scientitsts later proved). Each of these soils had less than 35% base saturation in the appropriate control section (deepest horizon to 180 cm). These soils were therefore classified as Ultisols due to the prescence of argillic horizons and the low base saturation.

Suborder, Great Group, and Subgroup

Two of these soils (T1 and T2) had redoximorphic features appearing below the organic horizons. Pedon T1 had a gleyed mineral horizon 10-cm beneath the organic layer, while site T2 did not exhibit a gleyed horizon until about 50-cm below the organic layers. Due to the wetness of these soils, they were both classified as Typic Endoaquults. Pedon T3 contained high amounts of organic carbon throughout the profile and was classified as a Haplohumult (must have 0.9% or greater OC in upper 15 cm of argillic horizon). This soil also showed evidence of wetness in the control sectction via redoximorphic depletions and concentrations (although, it was the driest of the three) and therefore was placed in the Aquic subgroup of the Haplohumults.

Family Classification

Because the two Endoaquults (T1 and T2) had greater than 35% rock fragments in their control section (the argillic horizon), they were classified in the loamy-skeletal particle size class. There was no dominant mineral in these soils therefore they were in the mixed mineralogy class. The Haplohumult (T3) was classified as having a fine particle size class due to the high amounts of clay in this soil in conjuntion with the low

presence of rock fragments. It also had mixed mineralogy. All terrace soils had an active CEC activity class (a ratio of CEC to clay between 0.4 and 0.6) and were located below 1088 m in elevation and therefore, had a mesic soil temperature regime (Carter and Ciolkosz, 1980).

Ridgetop soils

Soil Order

All R soils had cambic horizons, except for R3, which had an argillic horizon. As with the soils found on the terraces, this upland argillic soil was originally described as having a cambic horizon. Laboratory data show, however, that this pedon's illuvial horizon had enough clay increase to be argillic. Again, there was mention of "a few clay films" on the field report, so the appropriate classification change was made. The argillic soil had less than 35% base saturation in the control section (75 cm below the top to the fragipan) and therefore was classified as an Ultisol. The other three R soils (R1, R2, and R4) had cambic horizons and were classified as Inceptisols. Every soil occurring on a ridgetop had a fragipan.

Site R4 had a thin Bh horizon that was just thick enough to be deemed a spodic horizon (10 cm) and had other spodic properties, however, it was not recognized in classification due to a color discrepancy. In order to be considered a spodic horizon, the layer must be comprised of 85% or more spodic material. One of the criteria was a color of 5YR or redder. This particular horizon did indeed have this color; however, it only made up 70% of the horizon, and therefore was not enough to warrant the classification of spodic.

Suborder, Great Group, and Subgroup

Among the R soils, two were classified in a udic suborder because they were in a udic soil moisture regime: one udept (R2) and one udult (R3). The other two soils (R1 and R4) contained a gleyed horizon within 50 cm of the mineral surface and were classified in an aquic suborder (aquept). The Ultisol (R3) was initially classified as a humult because of the organic carbon content (1.1 %) in the upper 15 cm of the argillic horizon. The carbon value was determined via combustion and therefore was a "total C" value. In acidic soils, this number is generally synonymous with the organic C value. However, data from a previous study (Jenkins, 2001), showed that in mineral layers of forest soils, the total C value was often slightly higher (0.1 to 0.3%) than the organic C value. This soil had a total C value of 1.1% and the determining value was 0.9%. Taking this into consideration, this soil was reclassified to portray the pedon's stronger characteristic—the fragipan. Therefore, all soils were classified into a Fragi- great group. The two Fragiaquepts (R1 and R4) belonged to the Aeric subgroup due to color specifications (due to wetness). The Fragiudept and the Fragiudult both had redoximorphic features (concentrations and/or depletions) high enough in the profile (within 30 cm from the beginning of the mineral horizon) to warrant a subgroup classification of aquic.

Family Classification

All ridgetop soils had 15% or more fine sand or coarser fragments in the fraction less than 75 mm in diameter and had 18 to 35 % clay placing them in the fine-loamy

particle size class. There was no dominant mineral in these soils and therefore each was classified in the mixed mineralogy class. There were varied CEC activity classes. Pedons R1 and R4 were both superactive, having a CEC to clay ratio greater than 0.6. The Ultisol (R3) was active (ratio between 0.4 and 0.6), while the Aquic Fragiudept (R2) was semiactive (ratio between 0.24 and 0.6). All soils were classified as frigid because they occurred at elevations above 1088 m (Carter and Ciolkosz, 1980).

Sideslope soils

The soils occurring on the sideslope position have been divided into two categories—soils with cambic horizons and soils containing argillic horizons. There are three pedons in each of the two categories.

Soil Order

The three sideslope soils containing cambic horizons are all Inceptisols. One site (SSC2) was initially described as having an argillic horizon in the field, but after reviewing the laboratory particle size data, this pedon did not show sufficient clay increase to merit the inclusion of an argillic horizon. These horizons were subsequently classified as cambic and the horizon designations changed to Bw1 and Bw2.

Among the sideslope soils with argillic horizons, two (SSA2 and SSA3) had base saturations less than 35% in their lowest horizons and were classified as Ultisols. The third soil (SSA1) had a base saturation greater than 35% at its deepest horizon and was classified as an Alfisol. The Alfisol, though, appears to be weathering to an Ultisol, as observed by the subgroup of this soil (noted below). All three soils with argillic horizons

were formed from colluvial material from the Mauch Chunk formation. This geology is comprised of shale and mudstone, which contributed to the abundance of clay in these soils.

Suborder, Great Group, and Subgroup

Each of the cambic sideslope soils had a udic soil moisture regime and was classified in the udic suborder. Two of these soils (SSC2 and SSC3) were classified as Dystrudepts because they did not meet the qualifying characteristics for any other Udept great group and had a low base saturation. The other pedon (SSC1) contained a fragipan and hence was classified as a Fragiudept. This soil and SSC3 were classified in Typic subgroups, while the other Dystrudept (SSC2) contained an umbric epipedon and was classified in the Humic great group.

All soils with argillic horizons located on a sideslope also were located in a udic soil moisture regime and were classified in the udic suborder. Site SSA3 was initially classified as a humult due to the presence of moderately high organic carbon (OC) values in the control section (1.0 %), however, these values were borderline (the determining value being 0.9 %) and barely qualified as humic. Again, using the work of Jenkins (2001) which showed that mineral horizons in forest soils usually have slightly lower OC values than total C values, this soil was classified in the lower C category. Each of these three soils was typical and classified in the Haplo- great group. The two Ultisols (SSA2 and SSA3) had a Typic subgroup, while the Alfisol (SSA1), having a low base saturation for this order, was classified in the Ultic subgroup.

Family Classification

Each SSC soil had greater than 35% rock fragments in their control sections (between 25 cm and 100 cm below the mineral soil surface), had no dominant mineral, had a CEC/clay ratio greater than 0.6, and were below 1088 m (Carter and Ciolkosz, 1980). Therefore, all SSC soils had the same family classification—loamy-skeletal particle size class, mixed mineralogy, superactive CEC activity class, and a mesic soil temperature regime.

Two of the SSA soils (SSA2 and SSA3) had, in the fraction less than 75 mm in diameter, less than 15% particles of fine sand or coarser and 18 to 35% clay and hence, had a particle size class of fine-silty. The Alfisol (SSA1) also had between 18 and 35% clay but had less than 15% particles of fine sand or coarser and was classified as fine-loamy. No SSA soil had a dominant mineral and therefore, all had mixed mineralogy. All soils were below 1088 m and therefore in the mesic temperature regime (Carter and Ciolkosz, 1980). The CEC activity classes for SSA1 and SSA3 were active (CEC/clay ratio between 0.4 and 0.6), while the other Ultisol was superactive (CEC/clay ratio greater than 0.6).

EXTRACTABLE SULFATE AND SULFATE ADSORPTION POTENTIAL

Sulfate adsorption capacity is a major concern to the USFS, as well as others interested in forest management, especially in the northeastern U.S. where sulfate is the principal anion in acidic deposition. Knowing which soils are still capable of adsorbing sulfate is important because adsorption of sulfate by soils reduces the ionic strength of

soil solutions and thus reduces the leaching of polyvalent nutrient cations (Mitchell, et al., 1992; Fuller et al., 1985). The converse is also true: soils that are no longer adsorbing sulfate, sulfate saturated soils, are more susceptible to cation leaching (Harrison et al., 1989). Some factors affecting sulfate adsorption include pH, organic matter content, clay content, extractable sulfate, and soil texture (Adams et al., 2000; Prenzel and Meiwes, 1994; Mitchell et al.,1992; MacDonald and Hart, 1990).

Average sulfate adsorption potential was calculated for all of the Otter Creek soils (Fig. 10). What was being evaluated was the soil's ability to adsorb any additional sulfate on top of what was already there. Any negative values, those that fell below the 0-line, indicated that sulfate was being released into the system. Positive values showed that these horizons were capable of accepting sulfate. All A and E horizons were sulfate saturated and released sulfate upon equilibration. This agreed with data from MacDonald and Hart (1990). Using the same experimental procedure, they found all A horizons and some E horizons of Michigan forest soils also released sulfate into the soil system. Many studies suggest that this is due to high organic matter content in the A horizons masking the adsorption sites, and the coarse-textured nature of the E horizons not being conducive to adsorption (MacDonald and Hart, 1990; Mitchell et al., 1992; Adams et al., 2000; Fuller et al., 1985).

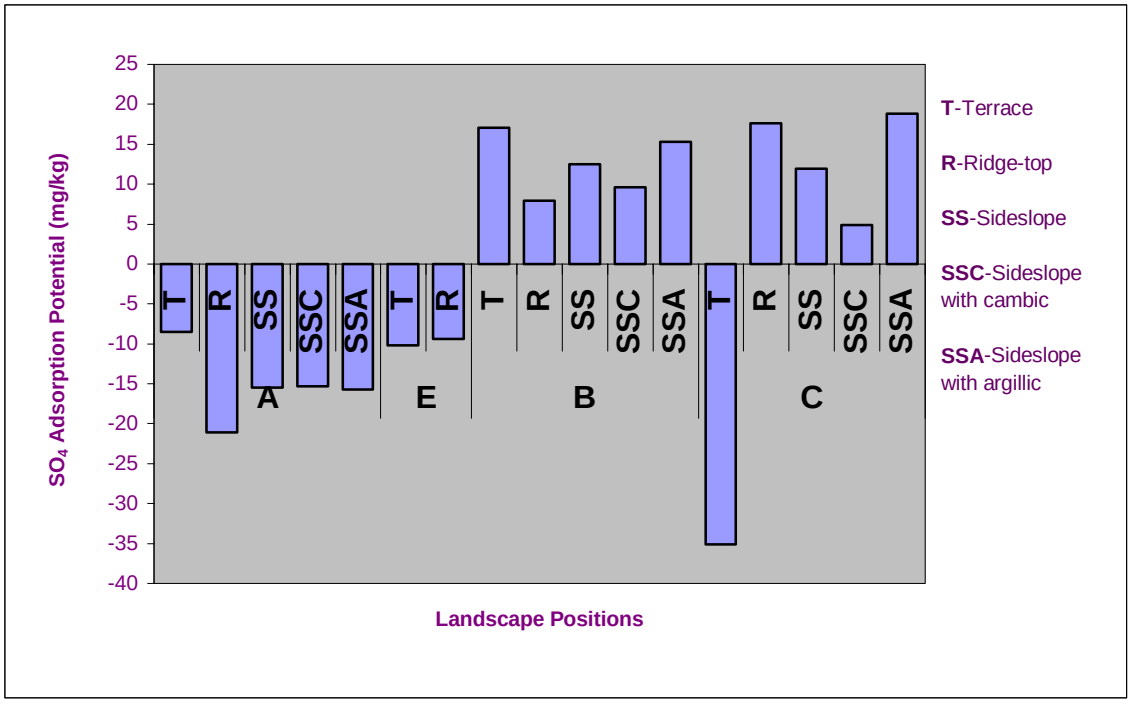

Figure 10. Index of sulfate adsorption potential for soil horizons in the Otter Creek Wilderness (neg. values=sulfate release; pos. values=soil capable of accepting sulfate).

As noted in Figure 10, C horizons in terrace soils appear to be heavily saturated with sulfate, however, this was not representative of the general trend of terrace C horizons. Site T1 had three Cg horizons that were out of character for T soils. In addition to the sulfate adsorption potential for these horizons being extremely negative, these layers also had very high extractable sulfate (Fig. 11) as well as a major increase in electrical conductivity (EC) (appendix A) when compared to the horizons above them. All other data for these horizons were congruent with the typical trends throughout the pedon and with other terrace soils. It was hypothesized that this could be an old surface horizon that has been buried and was portraying characteristics more representative of A horizons. This was unlikely though because the values reported for sulfate and EC were much higher in these Cg horizons than any data for A horizons in this or any pedon.

Another possibility for the elevated values could be due to a bog that was adjacent to this site. These were Cg horizons, which indicated that they were inundated for part of the year, perhaps with water from the bog running through it. The wetland environment is generally high in sulfur (and sulfate), with the potential to create pyritic salts, increasing ionic strength or EC (Stephens, 2002). Without having data from this bordering bog, it was difficult to say whether or not this was the influence that caused such elevated values in these Cg horizons. If we eliminated the outlier values and average the C horizons of the other T soils, the sulfate adsorption potential would be 17.7 mg/kg which was more representative of C horizons and indicates that these horizons were still capable of receiving and retaining sulfate.

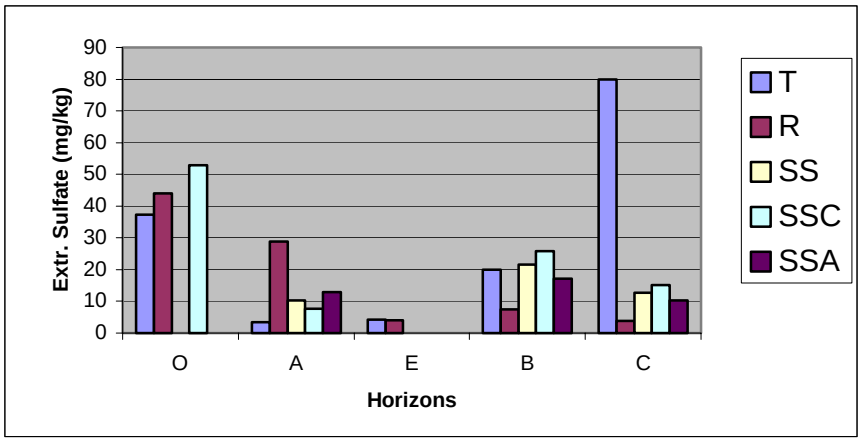

Figure 11. Extractable sulfate of soil horizons for various landscape positions in Otter Creek Wilderness

When we looked at the soils as a whole, R, SSC and SSA soils were capable of buffering this anion, with SSA soils having the greatest sulfate adsorption potential (Fig. 12). This could be due to the SSA soils having low organic carbon values in the B and C horizons, therefore there was less masking of the adsorption sites. Although, the SSA

soils had the most potential for adsorbing sulfate, there were no significant differences for sulfate adsorption within horizons or within whole pedons among landscape positions.

Again, the T soils reflected that they were beyond the maximum sulfate retention load, however, these values were skewed due to the three Cg horizons that were mentioned earlier. If these outlying values were omitted, terrace soils also had the capacity to retain sulfate. Like the SSA soils, T soils were also low in organic carbon in the B and C horizons.

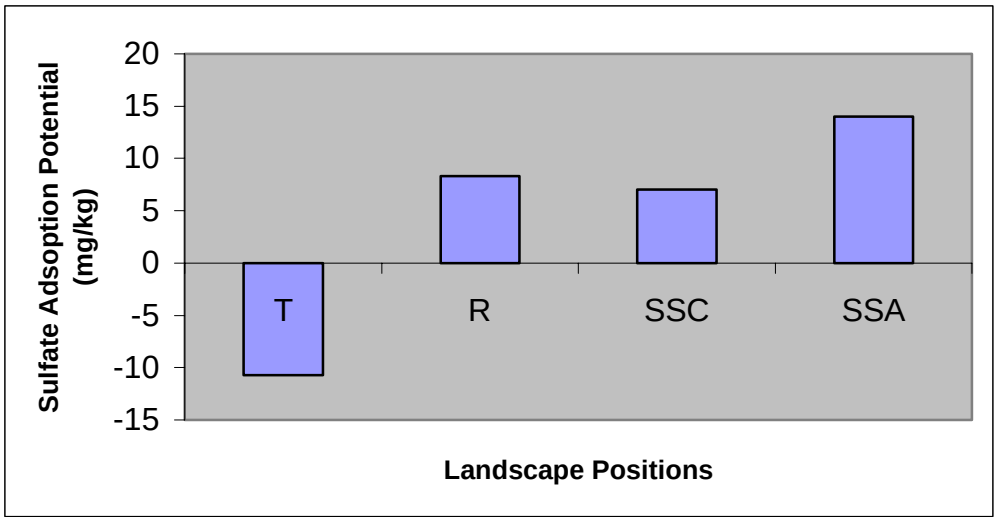

Figure 12. Sulfate adsorption potential of soils on various landscape positions in the Otter Creek Wilderness.

BIOMASS ACCUMULATION

When biomass data were calculated and analyzed, it was found that the data for the SSA sites were two to six times higher than data for any other site in this study. It was also found that these values were greater than any other site in West Virginia where

the NRCS had collected biomass data (Personal communication, Stephen Carpenter, State Soil Scientist, Morgantown, WV). Because of the highly elevated values at the SSA sites, Mr. Eric Wharton, Research Forester with the USFS and lead author of the publication (Wharton and Griffith, 1998) reporting the allometric equations used in this current study, was contacted. Wharton indicated that the regression equations used to estimate biomass were not applicable to very large trees, especially trees with DBH as great as 37 inches, which was the largest tree found in this study. Therefore, biomass data for the SSA sites were not reported in this thesis. This information does indicate, however, that these sites are producing the largest trees in the study (and also the most trees) and are therefore the most productive.

Average total vegetative biomass for the T, R, and SSC sites ranged from 241 to 261 Mg ha^{-1} (Table 10). Jenkins (2000) found similar results in the same region with biomass ranging from 159 to 297 Mg ha^{-1}. Biomass data for each individual tree species at each site and biomass data for each vegetative category are located in Appendix D.

Table 10. Biomass density of trees in Otter Creek with respect to landscape position

	Living (dbh>5")	Dead (dbh>5")	1-5"dbh	.1-1" dbh	Seedlings	Shrubs	Total
	----------	----------	----------	Mg ha^{-1}	----------	----------	----------
Terrace	212	<1	27	<1	<1	16	255 a[1]
Ridgetop	214	4	18	<1	<1	5	241 a
SSC[2]	225	8	26	2	<1	<1	261 a

[1]Values followed by the same letter are not significantly different ($p<0.05$).
[2]SSC = Sideslope soils with cambic horizons.

Rate of biomass accumulation followed the dame trends as the total biomass accumulation. Averages for pedons on the T, R, and SSC landscape positions ranged from 2.64 to 2.98 Mg ha^{-1} yr^{-1} (Table 11).

Table 11. Average stand age and biomass accumulation of soils in the Otter Creek Wilderness across various landscape positions.

Landscape	Average stand age	Total biomass accumulation	Rate of biomass accumulation
	yr	Mg ha^{-1}	Mg ha^{-1} yr^{-1}
Terrace	81	255 a[1]	2.95 a
Ridgetop	88	241 a	2.64 a
SSC[2]	87	261 a	2.98 a

[1]Values followed by the same letter are not significantly different ($p<0.05$).
[2]SSC = Sideslope soils with cambic horizons.

SUMMARY AND CONCLUSIONS

General Observations

Soils of Otter Creek Wilderness occurred on mostly acidic sandstone parent material, except for SSA soils which were forming in the Mauch Chunk geology. Sideslope soils were well drained and occurred on very steep slopes, while ridgetop and terrace soils were mostly somewhat poorly drained and poorly drained and occurred on nearly level to gently sloping landscapes. The vegetation of Otter Creek was mostly hardwood, deciduous species, with coniferous species mainly occurring on terrace soils and some on ridgetops.

Sideslope soils with argillic horizons were the healthiest soils in this study. They had the highest pH values of all the soils and the highest percent base saturation and

exchangeable Ca concentrations. It was found that these soils were at a low risk for acid toxicity and had the highest molar Ca:Al ratio. In addition, the SSA soils were still capable of adsorbing sulfate. Also, SSA soils had the most diverse vegetation.

Terrace soils and SSC soils demonstrated the most adverse conditions, with ridgetop soils generally having moderate conditions. Sideslope cambic and T soils were the most acidic, and had the lowest percent base saturation and exchangeable Ca concentrations. Furthermore, they had the highest extractable Al values and the lowest molar Ca:Al ratio. Terrace and R soils were at the highest risk for acid toxicity to fine roots and symbiotic fungi in the humus layer, while SSC soils were at a moderate risk. Terrace soils were sulfate saturated and were no longer accepting this anion.

Practical Applications

The soils of Otter Creek were highly acidic and had low nutrient status, except for the SSA soils because of their development on the nutrient rich, nutrient retainable Mauch Chunk geology. Many factors can affect the productivity of forests, however, for the Appalachian hardwood forests, the greatest threats to sustainable forestry are nutrient imbalances and acidity (Adams et al., 2000). Although, most forest soils have low pH values and thrive at these levels, soils in Otter Creek were extremely acid which has led to base cation release and decreased nutrient uptake by plants, as well as, introducing high levels of Al which can be toxic to plants. Some studies show that liming can amend some of these nutrient problems, however, the results are mixed. For instance, liming sugar maple stands in Pennsylvania restored more vigorous growth and canopy health (Long et al., 1997). Vance (1996) stated that long-term productivity of forests could be

enhanced by using wood-fired boiler ashes as a replacement for agricultural lime. On the other hand, liming can also induce nitrate leaching (Johnson et al., 1995) in addition to the desorption of sulfate from soil binding sites (Prenzel and Meiwes, 1994). Since most of these soils were already sulfate saturated, reducing the soils' ability to retain the anion through liming might not be the best management solution.

Low nutrient status was another problem plaguing the Otter Creek soils. Adding fertilizer, nutrient rich organic matter, or other amendments to increase base cations are some options for increasing fertility at these sites. However, there are mixed reports about whether or not adding nutrient amendments to large-scale forests is practical. Grigal (2000) stated that except in areas where liming has been used to alleviate nutrient imbalances due to extreme acidity, base cations are not routinely added to managed forests. This is due to the self-sufficiency of forests resulting from gradual shifts in nutrient pools as stands mature, which results in greater accumulation of nutrients in living biomass and detrital materials, the return of nutrients from the plant to the mineral soil, and the declining dependence of trees on the mineral soil to meet annual requirements in favor of internal retranslocation and nutrient release through decomposition of the forest floor (Grigal 2000). Spratt (1998) agreed, noting that litter input was the key to maintaining long-term surface soil nutrients. Interestingly, after applying organic matter amendments to his soils, Spratt found that the additions resulted in a loss of K, but a greater retention of Mg. Fertilizing with K has improved foliar nutrient status and growth rates in declining maples and additions of Ca and Mg led to improved tree vigor in some stands (McLaughlin and Percy, 1999). Additions of Ca have also increased foliar growth and Ca concentration of red spruce, but additions of Ca

associated with liming also have caused negative responses, usually attributed to altered soil chemistry due to change in pH (Grigal, 2000). However, as suggested by Grigal (2000), manipulations of Ca can be problematic because alterations of Ca in the soil affect the Ca-Al-pH interactions and markedly change the soil chemical status.

Obviously, there is much to research with respect to adding amendments to forested sites, and this discussion did not include economics and feasibility issues. If liming and fertilization are to be considered, they should be established specifically on a site-to-site basis because of inherent differences among soils and sites. With regards to Otter Creek, this area is a designated wilderness area and management is probably not an option. However, these data do have value for other non-wilderness sites, as well as, providing background data to the USFS for monitoring health of the forest in the wilderness.

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APPENDIX A

PROFILE DESCRIPTIONS

(Note: All horizon designations are shown how they appeared on the field description sheet).

Site: T1
Pedon: 99-83002
Location: Randolph County, West Virginia, Otter Creek above limer.

Classification: Loamy-skeletal, mixed, active, mesic Typic Endoaquults
Vegetation: Spruce, Hemlock
Slope: 2.5%
Parent Material: Alluvium, Colluvium
Physiography: Coalluvial terrace, dissected by histic, drains into adjacent bog.
Drainage class: Somewhat poorly drained
Elevation: 982 m
Latitude: N 38° 56' 44.5"
Longitude: W 79° 39' 55.1"

Described and sampled by Tony Jenkins, August 5, 1999 and August 24, 1999, respectfully.

Oi1,2 – 0 to 3 cm; 15 percent rock fragments; many very fine to coarse roots; extremely acid.
Oe – 3 to 7 cm; 15 percent rock fragments; many very fine to coarse roots; ultra acid; clear wavy boundary.
Oa – 7 to 15 cm; black (7.5YR 2.5/1) mucky loam; weak fine granular structure; very friable; 25 percent rock fragments; few fine to medium roots; ultra acid; abrupt wavy boundary.
E – 15 to 25 cm; grayish brown (10YR 5/2) loam; weak medium subangular blocky structure; friable; 25 percent rock fragments; few fine medium roots; extremely acid; clear wavy boundary.
EBg – 25 to 34 cm; 70% light brownish gray (10YR 6/2), 15% yellowish brown (10YR 5/8), and 15% very dark grayish brown (10YR 3/2) and (10YR 2/1) loam/sandy loam; weak medium and coarse subangular blocky structure; friable; 30 percent rock fragments; few fine to medium roots; extremely acid; gradual wavy boundary.
Bg1 – 34 to 51 cm; 60% light brownish gray (10YR 6/2) and 40% yellowish brown (10YR 5/6-8) clay loam; weak coarse prismatic to weak medium subangular blocky structure; friable; 30 percent rock fragments; few fine and medium roots; extremely acid; gradual wavy boundary.
Bg2 – 51 to 69 cm; 60% light brownish gray (10YR 6/2) and 40% strong brown (7.5YR 5/6-8) clay loam; weak coarse prismatic to weak medium subangular blocky structure; friable; 50 percent rock fragments; few fine roots; extremely acid; clear wavy boundary.
BC – 69 to 85 cm; 80% strong brown (7.5YR 5/6-8), 10% light brownish gray (10YR 6/2), and 10% pale brown (10YR 6/3) sandy clay loam; weak medium subangular blocky structure; friable; 50 percent rock fragments; very strongly acid; clear wavy boundary.
Cg1 – 85 to 110 cm; 90% (2.5Y 4/1) and 10% brown (7.5YR 4/4) sandy clay/sandy clay loam; massive; friable; 30 percent rock fragments; extremely acid; clear wavy boundary.
Cg2 – 110 to 121 cm; olive gray (5Y 4/2) sandy clay loam; massive friable; 30 percent rock fragments; extremely acid.

Note: This profile description appears how it was described in the field. However, after laboratory analyses, it was determined that both Bg horizons were actually Btg's. Also, this pedon was only described to Cg2, but a Cg3 horizon was sampled and laboratory data is present in Appendices B and C.

Site: T2
Pedon: 99-93006

Location: Randolph County, West Virginia, coalluvial terrace on Yellow Creek, near headwaters. About 150m west of McGowan Mountain Trail, 130m west of Yellow Creek.

Classification: Loamy-skeletal, mixed, active, mesic, Typic Endoaquults
Vegetation: Red spruce, hemlock, yellow birch, red maple, heavy rhododendron understory.
Slope: 5%
Parent Material: colluvium/alluvium from sandstone/shale
Physiography: coalluviual terrace/bench
Drainage class: Somewhat poorly drained
Elevation: 1030 m
Latitude: N 38^{o} 58' 26"
Longitude: W 79^{o} 41' 06.7"

Described and sampled by Tony Jenkins, August 4, 1999 and October 13, 1999, respectfully.

Oi1 – 0 to 2 cm; extremely acid.
Oe – 2 to 6 cm; ultra acid.
Oa– 6 to 12 cm; black (n 2/0); mucky sandy loam; 80 percent rock fragments; ultra acid.
E/A – 12 to 17 cm; black (7.5YR 2/1) and light brownish gray (10YR 6/2) gravelly, very fine sandy loam; 55 percent rock fragments; extremely acid.
E – 30 to 41 cm; grayish brown and light brownish gray (10YR 5-6/2) gravelly, very fine sandy loam; few fine (5YR 5/6) concentrations; 55 percent rock fragments; extremely acid.
Bw – 41 to 61 cm; yellowish brown (10YR 5/6) gravelly, very fine sandy clay loam; many coarse light brownish gray (10YR 6/2) depletions and many coarse (10YR 6/2) depletions; 55 percent rock fragments; extremely acid.
BCg – 61 to 79 cm; grayish brown and light brownish gray (10YR 5-6/2) gravelly, very fine sandy clay loam; many coarse yellowish brown (10YR 5/6) concentrations; 50 percent rock fragments; very strongly acid.
C – 79 to 99 cm; weak red (2.5YR 5/3) gravelly, very fine sandy loam; common medium yellowish brown (10YR 5/8) and strong brown (7.5YR 5/8) concentrations; 55 percent rock fragments; very strongly acid.
Cg –101 to 150+ cm; grayish brown (10YR 5/2) gravelly, very fine sandy clay loam; common medium yellowish brown (10YR5/8) and strong brown (7.5YR 5/8) concentrations; 50 percent rock fragments; very strongly acid.

Note: This profile description appears how it was described in the field. However, after laboratory analyses, it was determined that the Bw horizon was actually a Bt. Also, this pedon was described and sampled without the inclusion of a layer between 17 and 30 cm and a layer between 99 and 100 cm.

Site: T3
Pedon: 00-83002
Location: Randolph County, West Virginia, Along Otter Creek ½ mile below Limer

Classification: Fine, mixed, active, mesic Aquic Haplohumults
Vegetation: Yellow Birch, Red Maple, Hemlock, Very heavy Rhododendron
Slope: 4%
Stoniness: BLDY overall
Parent Material: Sandstone (alluvial over alluvial or coalluvial)
Physiography: High floodplain/ low terrace
Drainage class: Moderately well drained
Elevation: 957 m
Latitude: N 38^{o} 57' 00.2"
Longitude: W 79^{o} 40' 04.7"
Additional Notes: Area of fine to fine silty mantle (0-1m) thick over sandstone-SIC layer. Pockets of thick Mn concentration in B horizons.

Described and sampled by Tony Jenkins, October 31, 2000.

Oi1 – 2 to 0 cm; extremely acid; abrupt wavy boundary.
Oi2 – 0 to 3 cm; extremely acid.
Oe – 3 to 9 cm; ultra acid; abrupt wavy boundary.
A – 9 to 18 cm; black (7.5YR 2.5/1) silt loam; 20 percent dark grayish brown (10YR4/2); moderate fine granular structure; very friable; 5% rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
B/A– 18 to 28 cm; 70 percent yellowish brown, dark grayish brown (10YR 5/6, 4/2) silt loam; 30 percent black (10YR2/1); moderate fine to medium subangular blocky structure; friable; 5 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bw1 – 28 to 51 cm; yellowish brown (10YR 5/6) silt loam; weak medium subangular blocky structure; friable; 5 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bw2 – 51 to 93 cm; yellowish brown (10YR 5/6) silty clay loam; common medium light brownish gray (10YR 6/2) depletions and few fine strong brown (7.5YR 4/6) concentrations; weak medium subangular blocky structure; friable; 5 percent rock fragments; many fine to coarse roots; very strong acid; clear wavy boundary.
BC – 93 to 118 cm; yellowish brown (10YR 5/6) silty clay loam; many medium light brownish gray (10YR 6/2) depletions and common fine strong brown (7.5YR 5/8) concentrations; weak medium subangular blocky structure; friable; 60 percent rock fragments; many fine to coarse roots; very strong acid; clear wavy boundary.
Cg– 118 to 170+ cm; light brownish gray (2.5Y and 10YR 6/2) silty clay loam; common medium light brownish gray (10YR 6/2) depletions and common medium to coarse yellowish brown (10YR 5/8) concentrations; massive; friable; 70 percent rock fragments; many fine to medium roots; very strong acid.

Note: This profile description appears how it was described in the field. However, after laboratory analyses, it was determined that both Bw horizons were actually Bt's.

Site: R1
Pedon: 99-93002

Location: Randolph County, West Virginia, head of Devil's Gulch, on dissected ridgetop position.

Classification: Fine-loamy, mixed, superactive, frigid Aeric Fragiaquepts
Vegetation: Red maple, beech, cherry, yellow birch, hayscented fern
Slope: 4 %
Parent Material: mud-flow, shale, colluvium
Physiography: broad ridgetop
Drainage class: Somewhat poorly drained (redox features say poorly, but not hydric site)
Elevation: 1090 m
Latitude: N 38° 59' 00.3"
Longitude: W 79° 40' 13.5"

Described and sampled by Tony Jenkins, August 11, 1999 and August 25, 1999, respectfully.

Oi– 0 to 2 cm; many very fine to coarse roots; extremely acid; abrupt wavy boundary.

Oa – 2 to 3 cm; very dark brown (10YR 2/2) mucky silt loam; weak fine and medium granular structure; very friable; 5 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.

A – 3 to 8 cm; very dark brown (10YR 2/2) silt loam; weak medium granular structure; very friable; 5 percent rock fragments; common fine to coarse roots; ultra acid; clear wavy boundary.

B/E – 8 to 15 cm; 50% yellowish brown (10YR 5/6), 30% light yellowish brown (2.5Y 6/3) and 20% dark yellowish brown (10YR 4/4) silt loam; moderate medium and coarse subangular blocky structure; friable; 5 percent rock fragments; few fine roots; extremely acid; clear wavy boundary.

Bw – 15 to 46 cm; yellowish brown (10YR 5/8) clay loam; light yellowish brown (2.5Y 6/3) on ped faces; common coarse light brownish gray (10YR 6/2) depletions; weak coarse prismatic to moderate fine and medium subangular blocky structure; friable; common, fine manganese concentrations; 10 percent rock fragments; clear wavy boundary.

Bgx1 – 46 to 68 cm; dark gray (n 4/0) clay loam; coarse prismatic structure; firm; 5 percent rock fragments; very strongly acid; clear wavy boundary.

Bgx2 – 68 to 125 cm; dark gray (n 4/0) silt loam; coarse prismatic structure; firm; 5 percent rock fragments; very strongly acid; abrupt wavy boundary.

C – 125 to 150+ cm; 60% yellowish brown (10YR 5/8) and 40% olive brown (2.5Y 5/3) silt loam; common coarse gray (10YR 5/1) depletions; massive; friable; 10 percent rock fragments; very strongly acid.

Site: R2
Pedon: 00-83001

Location: Randolph County, West Virginia—near the Stuart Gap side of Otter Creek entrance on road to Bear Haven.

Classification: Fine-loamy, mixed, semiactive, frigid Aquic Fragiudepts
Vegetation: Red maple, red spruce, cherry, beech, yellow birch
Slope: 3%
Parent Material: Shale and sandstone, colluvium
Physiography: Ridgetop
Drainage class: Poorly drained
Elevation: 1160 m
Latitude: N 38° 56' 37"
Longitude: W 79° 41' 57.2"

Described and sampled by Tony Jenkins, August 7, 2000.

Oi1 – 0 to 1 cm; very strongly acid.
Oi2 – 1 to 3 cm; extremely acid.
A – 3 to 10 cm; very dark brown (10YR 2/2) silt loam; weak fine granular structure; friable; 10 percent rock fragments; many very fine to coarse roots; ultra acid; clear wavy boundary.
AB – 10 to 16 cm; brown (10YR 4/3) silt loam; weak medium subangular blocky structure; friable; 10 percent rock fragments; many very fine to medium roots; ultra acid; clear wavy boundary.
Bw1 – 16 to 30 cm; light yellowish brown (10YR 6/4) loam; 30 percent strong brown (7.5YR 5/6) and 10 percent brown (10YR 5/3) concentrations; 10 percent grayish brown (10YR 5/2) depletions; weak medium subangular blocky structure; friable; 10 percent rock fragments; common fine roots; extremely acid; clear wavy boundary.
Bw2 – 30 to 44 cm; light yellowish brown (10YR 6/4) loam; 30 percent strong brown (7.5YR 5/6) concentrations and 20 percent grayish brown (10YR 5/2) depletions; weak medium subangular blocky structure; friable; 20 percent rock fragments; few fine to medium roots; extremely acid; clear wavy boundary.
Bw3 – 44 to 70 cm; light yellowish brown (10YR 6/4) clay loam; 50 percent strong brown (7.5YR 5/6) and 10 percent dark yellowish brown (10YR 3/4) concentrations; 20 percent gray (10YR 5/1) depletions; weak medium and coarse subangular blocky structure; friable; 15 percent rock fragments; few fine and medium roots; very strongly acid; gradual wavy boundary.
Bx – 70 to 110 cm; yellowish brown (10YR 5/4) clay loam; 20 percent strong brown (7.5YR 5/6) concentrations and 20 percent gray (10YR 5/1) depletions; weak coarse prismatic structure; firm; 15 percent rock fragments; very strongly acid; clear wavy boundary.
C – 110 to 150+ cm; brown (10YR 4/3) loam; 5 percent gray (10YR 5/1) depletions; massive; 40 percent rock fragments; very strongly acid.

Site: R3
Pedon: 00-93001
Location: Tucker County, West Virginia

Classification: Loamy-skeletal, mixed, active, frigid Aquic Fragiudults
Vegetation: Hemlock, yellow birch, cherry, red maple, red spruce, rhododendron
Slope: 1%
Parent Material: Sandstone and shale, colluvium, frost-wedge heave from periglacial activity
Physiography: Broad ridgetop
Drainage class: Somewhat poorly drained
Elevation: 1120 m
Latitude: N 39° 00' 52"
Longitude: W 79° 40' 04"
Additional Notes: Boulder size flags of sandstone and shale at 70° upward west from greater them 60" up to 3'. Pedon contains pockets of Bh material. Few clay films at bottom of Bw.

Described and sampled by Tony Jenkins, August 8, 2000.

Oi1 – 0 to 1 cm; 90 percent rock fragments; extremely acid.
Oi2 – 1 to 4 cm; 90 percent rock fragments; extremely acid.
Oe – 4 to 7 cm; reddish brown (5YR 3/3); 90 percent rock fragments; extremely acid.
Oa1 – 7 to 29 cm; black (N 2/0); very friable; 90 percent rock fragments; many very fine to very coarse roots; ultra acid; clear wavy boundary.
Oa2 – 29 to 42 cm; black (10YR 2/1); weak fine granular structure; very friable; 90 percent rock fragments; many very fine to very coarse roots; abrupt wavy boundary.
E – 42 to 55 cm; gray (10YR 6/1) and light brownish gray (10YR 6/2) sandy loam; gray (7.5YR 6/1) depletions; weak medium subangular blocky structure; firm; 50 percent rock fragments; few fine to coarse roots; extremely acid; abrupt wavy boundary.
Bw – 55 to 75 cm; yellowish brown (10YR 5/6) loam; gray (10YR 6/1) depletions and brownish yellow (10YR 6/8) concentrations; weak medium subangular blocky structure; friable; 35 percent rock fragments; few medium roots; extremely acid; clear wavy boundary.
Bx – 75 to 120 cm; dark yellowish brown (10YR 4/4) loam; gray (10YR 6/1) prism coatings; weak coarse prismatic to weak medium subangular blocky structure; firm; 60 percent rock fragments; extremely acid; clear wavy boundary.
Cg – 120 to 150+ cm; dark grayish brown (10YR 4/2) and gray (10YR 5/1) silty clay loam/ clay loam; yellowish brown (10YR 5/6) concentrations; massive; firm; 90 percent rock fragments; extremely acid.

Note: This profile description appears how it was described in the field. However, after laboratory analyses, it was determined that the Bw and Bx horizons were actually a Bt and a Btx, respectively.

Site: R4
Pedon: 00-93003
Location: Randolph County, West Virginia

Classification: Loamy-skeletal, mixed, superactive, frigid Aeric Fragiaquepts
Vegetation: Hemlock, red spruce, yellow birch
Slope:4 %
Parent Material: Sandstone and shale, colluvium
Physiography: Broad ridgetop
Drainage class: Poorly drained
Elevation: 1120 m
Latitude: N 38° 59' 10.8"
Longitude: W 79° 36' 47.9"

Described and sampled by Tony Jenkins, August 10, 2000.

Oi1 – 1 to 0 cm; many very fine to coarse roots; extremely acid; abrupt wavy boundary.
Oi2 – 0 to 2 cm; 50 percent roots; many very fine to coarse roots; extremely acid; clear wavy boundary.
Oe – 2 to 4 cm; 50 percent roots; many very fine to coarse roots; clear wavy boundary.
Oa/A – 4 to 12 cm; black (7.5YR 2.5/1); weak fine granular structure; 50 percent roots; many very fine to coarse roots; extremely acid; abrupt wavy boundary.
Eg – 12 to 20 cm; brown-pinkish gray (7.5YR 5-6/2) sandy loam; common fine and medium brownish yellow and yellowish brown (10YR5/6 and 6/6) and common fine pale brown (10YR 6/3) concentrations; weak medium to coarse subangular blocky structure; firm; 40 percent rock fragments; few fine to medium roots; extremely acid; abrupt wavy boundary.
Bh/Bw – 20 to 30 cm; 70 percent dark reddish brown (5YR 3/2) loam; 30 percent yellowish brown (10YR5/6) concentrations; moderate fine to medium subangular blocky structure; friable; 30 percent rock fragments; few fine to medium roots; extremely acid; abrupt broken boundary.
Bw – 30 to 44 cm; yellowish brown (10YR 5/6) sandy clay loam; common fine yellowish red (5YR 5/6), strong brown (7.5YR5/6) concentrations and (2.5Y 6/2) depletions; weak medium subangular blocky structure; friable; 20 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bx – 44 to 75 cm; yellowish brown (10YR 5/6) sandy loam; common medium and coarse weak red (2.5YR 6/2) depletions; weak coarse prismatic structure; very firm; 20 percent rock fragments; extremely acid; clear wavy boundary.
BCg – 75 to 100 cm; gray (2.5Y 6/1) sandy clay loam; common fine and medium yellowish brown (10YR 5/6) concentrations; weak very coarse prismatic structure; firm; 25 percent rock fragments; very strong acid; gradual wavy boundary.
Cg – 100 to 150+ cm; gray (2.5Y 5/1) silty clay loam; common fine yellowish brown (10YR 5/6) concentrations and reddish gray (2.5Y 7/1) depletions; massive; firm; 50 percent rock fragments; very strong acid.

Site: SSC1
Pedon: 99-83001
Location: Randolph County, West Virginia

Classification: Loamy-skeletal, mixed, superactive, mesic Typic Fragiudepts
Vegetation: Red maple, yellow birch, frasier magnolia, under story beech, spruce
Slope: 45%
Parent Material: Pottsville colluvium
Physiography: Backslope
Drainage class: Well drained
Aspect: SW
Elevation: 1010 m
Latitude: N 38^{o} 56' 49.5"
Longitude: W 79^{o} 39' 50.1"
Additional Notes: This pedon included a nearly folistic, fragmental area of thickened A A/E. it had some spodic character underlying.
Right (other) side of pedon description: **A** –70% rocks, to 76 cm, **Bs**-- 76-89 cm, 7.5YR 4/6, then into Bw, other horizons same as below.
Very poor vegetation, but not unusual for the S facing slopes of this area.

Described and sampled by Tony Jenkins, August 3, 1999 and August 24, 1999, respectfully.

Oi1 – 0 to 3 cm; extremely acid.
Oi2 – 3 to 6 cm; 30 percent rock fragments; common fine and very fine roots; extremely acid; clear wavy boundary.
Oe – 6 to 8 cm; 30 percent rock fragments; many very fine to coarse roots; ultra acid; clear wavy boundary.
Oa/A – 8 to 15 cm; black (7.5YR2.5/1); weak medium granular structure; very friable; 45 percent rock fragments; many very fine to coarse roots; ultra acid; clear irregular boundary.
A/E – 15 to 30 cm; very dark grayish brown, pale brown, and dark yellowish brown (10YR 3/2, 6/3, 4/6) loam; weak fine and medium subangular blocky structure; friable; 50 percent rock fragments; many very fine to coarse roots; ultra acid; clear broken boundary.
BE – 30 to 58 cm; yellowish brown and pale brown (10YR 5/4 and 6/3) silt loam; weak fine and medium subangular blocky structure; friable; 50 percent rock fragments; common very fine to coarse roots; extremely acid; clear broken boundary.
Bw – 58 to 89 cm; yellowish brown (10YR 5/6) silt loam; weak medium subangular blocky structure; friable; 40 percent rock fragments; few very fine to coarse roots; extremely acid; clear wavy boundary.
Bx – 89 to 125 cm; yellowish brown (10YR 5/4) loam; weak medium subangular blocky structure; very firm; 50 percent rock fragments; very strongly acid; clear wavy boundary.
Cx – 125 to 170+ cm; yellowish brown (10YR 5/4) sandy loam; massive; firm; 65 percent rock fragments; very strongly acid

Site: SSC2
Pedon: 99-93005
Location: Tucker County, West Virginia, about 250m north of Otter creek, about 300m west of Coal Run.

Classification: Loamy-skeletal, mixed, superactive, mesic, Humic Dystrudepts
Vegetation: Poplar, red oak, beech, sugar maple, basswood
Slope: 68%
Parent Material: Mauch Chunk colluvium
Physiography: mid-backslope
Drainage class: Well drained
Aspect: 62^{o} NE
Elevation: 670m
Latitude: N 39^{o} 02' 22.7"
Longitude: W 79^{o} 37' 26.2"

Described and sampled by Tony Jenkins, August 19, 1999 and October 5, 1999, respectfully.

Oi1 – 0 to 2.5 cm; strongly acid.
Oi2 – abrupt wavy boundary.
A– 2.5 to 9 cm; dark reddish brown (5YR 3/3) silt loam; weak fine granular structure; very friable; 15 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
BA – 9 to 30 cm; dusky red (2.5YR 3/3) silt loam; weak fine and medium subangular blocky structure; friable; 15 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bt1 – 30 to 41 cm; dusky red (2.5YR 3/4) silt loam; weak fine and medium subangular blocky structure; friable; 20 percent rock fragments; few fine, thin, discontinuous clay films; many very fine to coarse roots; extremely acid; gradual wavy boundary.
Bt2 – 41 to 61 cm; dusky red (2.5YR 3/4) silt loam; weak medium subangular blocky structure; friable; 35 percent rock fragments; few fine, thin, discontinuous clay films; common fine and medium roots; extremely acid; clear wavy boundary.
BC – 61 to 79 cm; dusky red (2.5YR 3/4) silt loam; weak fine and medium subangular blocky structure; friable; 50 percent rock fragments; common fine and medium roots; extremely acid; gradual wavy boundary.
C – 79 to 99 cm; dusky red (2.5YR 3/4) silt loam; massive; friable; 80 percent rock fragments; few fine roots; extremely acid; abrupt wavy boundary.

Note: This profile description appears how it was described in the field. However, after laboratory analyses, it was determined that the Bt horizons did not have enough of a clay increase to warrant an argillic horizon and therefore were classified as Bw1 and Bw2.

Site: SSC3
Pedon: 00-93002
Location: Randolph County, West Virginia

Classification: Loamy-skeletal, mixed, superactive, mesic Typic Dystrudepts
Vegetation: Red Maple, Cherry, Cucumber Maple, Mountain Magnolia
Slope: 38%
Parent Material: Sandstone, colluvium
Physiography: Steep side slope
Drainage class: Well drained
Aspect: NE
Elevation: 939 m
Latitude: N 38° 58' 13.3"
Longitude: W 79° 37' 59.3"

Described and sampled by Tony Jenkins and Jason Teets, August 9, 2000.

Oi1 – 2 to 0 cm; very strongly acid.
Oi2 – 0 to 2 cm; very strongly acid.
Oe – 2 to 6 cm; extremely acid.
Oa/A – 6 to 11 cm; black (10YR 2/1) silt loam; 50 percent rock fragments; many very fine to coarse roots; ultra acid; clear wavy boundary.
AB – 11 to 19 cm; dark yellowish brown (10YR 3/4) silt loam/loam; few fine light olive brown (2.5Y 5/3) and strong brown (7.5YR 5/6) concentrations; weak medium to fine subangular blocky structure; very friable; 40 percent rock fragments; many very fine to coarse roots; ultra acid; clear wavy boundary.
Bw1 – 19 to 35 cm; dark yellowish brown (10YR 4/6) silt loam; weak medium to fine subangular blocky structure; friable; 40 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bw2 – 35 to 65 cm; yellowish brown (10YR 5/6) silt loam; weak medium to fine subangular blocky structure; friable; 40 percent rock fragments; common very fine to coarse roots; extremely acid; gradual wavy boundary.
Bw3 – 65 to 85 cm; light olive brown (2.5Y 5/6) silt loam; weak medium to fine subangular blocky structure; friable; 40 percent rock fragments; few very fine to medium roots; extremely acid; gradual wavy boundary.
BC – 85 to 113 cm; light olive brown (2.5Y 5/6) loam; weak medium to fine subangular blocky structure; friable; 60 percent rock fragments; few fine to medium roots; very strongly acid; clear wavy boundary.
C1 – 113 to 138 cm; 60 percent light olive brown (2.5Y 5/6) and 40 percent light olive brown (2.5Y 5/4) loam; few fine light yellowish brown (2.5Y 6/3) and strong brown (7.5YR 5/6) concentrations; massive; firm; 80 percent rock fragments; very strongly acid; clear wavy boundary.
C2 – 138 to 160 cm; 50 percent light olive brown (2.5Y 5/4) and 50 percent olive brown (2.5Y 4/3) loam; massive; very firm; 85 percent rock fragments; extremely acid.

Site: SSA1
Pedon: 99-93001

Location: Tucker County, West Virginia, about 0.7 miles out Turkey Run Trail from Fernow entrance (near Big Springs Gap).

Classification: Fine-loamy, mixed, active, mesic Ultic Hapludalfs
Vegetation: Poplar, red oak, sugar maple, basswood, beech, ramps
Slope: 50%
Parent Material: Mauch Chunk colluvium
Physiography: Upper backslope
Drainage class: Well
Aspect: E
Elevation: 847 m
Latitude: N 39^{o} 02' 16.0"
Longitude: W 79^{o} 39' 31.6"

Described and sampled by Tony Jenkins, August 10, 1999 and August 23, 1999, respectfully.

Oi– 0 to 2.5 cm; abrupt wavy boundary; slightly acid.

A1 – 2.5 to 7 cm; dark brown (7.5YR 3/2) silt loam; moderate fine and medium granular structure; very friable; 20 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.

A2 – 7 to 13 cm; dark brown (10YR 3/3) silt loam; moderate medium granular structure; very friable; 25 percent rock fragments; many very fine to coarse roots; clear wavy boundary.

BA – 13 to 19 cm; reddish brown (5YR 4/3) silt loam; weak fine and medium subangular blocky structure; friable; 20 percent rock fragments; common fine to coarse roots; extremely acid; clear wavy boundary.

Bt1 – 19 to 53 cm; reddish brown (5YR 4/4) silty clay loam; weak medium subangular blocky structure; friable; 20 percent rock fragments; few, thin, discontinuous, patchy clay films; common fine to coarse roots; very strongly acid; clear wavy boundary.

Bt2 – 53 to 75 cm; reddish brown (5YR 4/4) clay loam; weak medium subangular blocky structure; firm; 20 percent rock fragments; few, thin, discontinuous, patchy clay films; few fine roots; very strongly acid; gradual wavy boundary.

Bt3 – 75 to 113 cm; reddish brown (5YR 4/4) clay loam; weak medium subangular blocky structure; firm; 35 percent rock fragments; few, thin, discontinuous, patchy clay films; few fine roots; very strongly acid; gradual wavy boundary.

BC – 113 to 137 cm; reddish brown (5YR 4/4) loam; weak medium subangular blocky structure; firm; 40 percent rock fragments; few fine roots; very strongly acid; gradual wavy boundary.

C – 137 to 160+ cm; reddish brown (5YR 4/4) loam; massive; firm; 55 percent rock fragments; very strongly acid.

Site: SSA2
Pedon: 99-93003
Location: Tucker County, West Virginia.

Classification: Fine-silty, mixed, superactive, mesic Typic Hapludults
Vegetation: Poplar, red oak, locust, beech, sugar maple, red maple
Slope: 44%
Parent Material: Mauch Chunk colluvium
Physiography: lower backslope/ steep footslope
Drainage class: Well drained
Aspect: 210^{o} SW
Elevation: 650 m
Latitude: N 39^{o} 02' 38.2"
Longitude: W 79^{o} 37' 30.3"

Described and sampled by Tony Jenkins, August 12, 1999 and August 26, 1999, respectfully.

Oi1 – 0 to 1 cm; moderately acid.
Oi2 – 1 to 3 cm; moderately acid; abrupt wavy boundary.
A – 3 to 14 cm; dark brown (7.5YR 3/2) silt loam; moderate very fine and fine granular structure; very friable; 30 percent rock fragments; common very fine to medium roots; extremely acid; clear wavy boundary.
BA– 14 to 34 cm; brown (7.5YR 4/4) silt loam; weak medium subangular blocky structure; very friable; 20 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.
Bt1 – 34 to 60 cm; reddish brown (5YR 4/4) silty clay loam; weak medium subangular blocky structure; friable; 25 percent rock fragments; few, thin, discontinuous, patchy clay films; common very fine to medium roots; extremely acid; gradual wavy boundary.
Bt2 – 60 to 107 cm; reddish brown (5YR 4/4) silt loam; weak medium subangular blocky structure; friable; 30 percent rock fragments; few, thin, discontinuous, patchy clay films; few very fine to medium roots; very strongly acid; gradual wavy boundary.
BC – 107 to 138 cm; dusky red (2.5YR 3/4) silt loam; weak medium subangular blocky structure; firm; 40 percent rock fragments; few very fine to medium roots; very strongly acid; gradual wavy boundary.
C – 138 to 152 cm; dusky red (2.5YR 3/4) silt loam; massive; firm; 40 percent rock fragments; few very fine to medium roots; very strongly acid.

Site: SSA3
Pedon: 99-93004
Location: Tucker County, West Virginia.

Classification: Fine-silty, mixed, active, mesic Typic Hapludults
Vegetation: Red oak, locust, beech, red maple
Slope: 59%
Parent Material: Mauch Chunk colluvium
Physiography: Midslope shoulder/ backslope
Drainage class: Well drained
Aspect: N
Elevation: 662 m
Latitude: 39° 2'42.55"N
Longitude: 79°37'31.75"W
Additional Notes: I received organic horizons for this pedon but none were described.

Described and sampled by Tony Jenkins, August 19, 1999 and August 16, 1999, respectfully.

A1 – 0 to 2 cm; black (7.5YR 2.5/1) silt loam; weak fine and medium granular structure; very friable; 15 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.

A2– 2 to 7 cm; dark brown (7.5YR 3/2) silt loam; weak medium and coarse granular structure; very friable; 15 percent rock fragments; many very fine to coarse roots; clear wavy boundary.

AB – 7 to 12 cm; dark brown (7.5YR 3/4) silt loam; weak fine subangular blocky structure; very friable; 20 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.

BA – 12 to 29 cm; brown (5YR 4/3) silt loam; moderate fine subangular blocky structure; friable; 20 percent rock fragments; many very fine to coarse roots; extremely acid; clear wavy boundary.

Bt – 29 to 65 cm; brown (5YR 4/4) silt loam; weak fine and medium subangular blocky structure; friable; 30 percent rock fragments; few patchy, thin, discontinuous clay films; common very fine to medium roots; extremely acid; gradual wavy boundary.

BC – 65 to 86 cm; brown (5YR 4/4) silt loam; weak fine and medium subangular blocky structure; friable; 40 percent rock fragments; common very fine to medium roots; extremely acid; clear wavy boundary.

C – 86 to 101 cm; brown (5YR 4/4) silt loam; massive; friable; 60 percent rock fragments; few fine roots; very strongly acid; abrupt wavy boundary.

APPENDIX B

SOIL PHYSICAL DATA FOR EACH PEDON

(Note: All horizon designations are shown how they appeared on the field description sheet).

Table 12. T1~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt)	Bulk Density (frame) (Mg m^{-3})	Bulk Density (clod) (Mg m^{-3})
Oi1 & Oi2	0-3	0.00	0.07	N/A
Oe	3-7	0.00	0.16	N/A
Oa	7-15	1.24	0.22	N/A
E	15-25	0.18	N/A	1.6
EB g	25-34	1.60	N/A	1.6
Bg1	34-51	10.12	N/A	1.7
Bg2	51-69	12.86	N/A	1.7
BC	69-85	9.34	N/A	1.7
Cg1	85-110	21.11	N/A	1.9
Cg2	110-121	23.64	N/A	1.9
Cg3	121-160+	24.80	N/A	2.0

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		(%)				
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-7	N/A	N/A	N/A	N/A	N/A
Oa	7-15	N/A	N/A	N/A	N/A	N/A
E	15-25	0.4	2.0	13.7	19.4	8.7
EB g	25-34	0.7	3.6	18.4	22.9	7.1
Bg1	34-51	1.6	4.2	14.6	18.4	6.1
Bg2	51-69	3.5	7.7	21.1	18.4	4.6
BC	69-85	1.1	3.0	18.3	27.6	6.3
Cg1	85-110	4.1	12.4	18.2	22.2	9.1
Cg2	110-121	5.6	12.6	17.2	21.4	9.1
Cg3	121-160+	5.6	13.6	18.8	20.6	8.2

Horizon	Depth (cm)	Sand	Silt	Clay	FT	LT
		(%)				
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-7	N/A	N/A	N/A	N/A	N/A
Oa	7-15	N/A	N/A	N/A	N/A	N/A
E	15-25	44.2	41.3	14.5	L	L
EB g	25-34	52.7	35.3	12.0	L	SL/L
Bg1	34-51	44.6	35.5	19.9	CL	L
Bg2	51-69	55.3	20.6	24.1	CL	SCL
BC	69-85	56.0	24.2	19.8	SCL	SL/SCL
Cg1	85-110	59.4	32.0	8.6	SCL	SL
Cg2	110-121	59.1	33.2	7.6	SCL	SL
Cg3	121-160+	61.1	32.0	6.9	N/A	SL

FT Field Texture LT Laboratory Texture

Table 13. T2~ Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi	0-2	2.25	0.09	N/A
Oe	2-6	2.67	N/A	N/A
Oa	6-12	3.85	0.09	N/A
EA	12-17	50.21	N/A	1.8
E	30-41	36.99	N/A	1.9
Bw	41-61	26.02	N/A	1.8
BCg	61-79	36.80	N/A	2.0
C	79-99	26.75	N/A	1.6
Cg	101-150+	28.81	N/A	1.8

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		(%)				
Oi	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	N/A	N/A	N/A	N/A	N/A
Oa	6-12	N/A	N/A	N/A	N/A	N/A
EA	12-17	19.1	11.5	11.6	17.8	4.3
E	30-41	12.8	10.8	11.3	16.8	5.9
Bw	41-61	15.9	11.3	9.7	11.3	4.6
BCg	61-79	16.2	12.1	12.6	10.7	3.4
C	79-99	19.0	16.3	17.3	12.0	4.2
Cg	101-150+	23.3	14.4	10.2	7.0	3.3

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		(%)				
Oi	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	N/A	N/A	N/A	N/A	N/A
Oa	6-12	N/A	N/A	N/A	N/A	N/A
EA	12-17	64.4	30.5	5.1	SL	SL
E	30-41	57.8	36.1	6.1	SL	SL
Bw	41-61	52.9	31.7	15.4	SCL	SL/L
BCg	61-79	55.4	35.8	8.8	SCL	SL
C	79-99	68.8	23.2	8.0	SL	SL
Cg	101-150+	58.5	26.0	15.6	SCL	SL

FT* Field Texture LT** Laboratory Texture

Table 14. T3~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	2-0	0.00	N/A	N/A
Oi2	0-3	0.00	N/A	N/A
Oe	3-9	0.00	N/A	N/A
A	9-18	0.00	N/A	N/A
B/A	18-28	0.00	N/A	N/A
Bw1	28-51	0.00	N/A	1.0
Bw2	51-93	0.00	N/A	1.3
BC	93-118	0.04	N/A	1.3
Cg	118-170+	0.06	N/A	1.5

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth	Sand				
	(cm)	v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-9	N/A	N/A	N/A	N/A	N/A
A	9-18	0.2	0.8	3.7	6.6	6.0
B/A	18-28	0.1	0.4	3.3	6.4	6.2
Bw1	28-51	0.2	0.8	2.7	4.7	4.6
Bw2	51-93	0.4	1.7	3.1	4.2	4.9
BC	93-118	0.8	1.2	2.2	3.4	5.2
Cg	118-170+	0.6	0.9	2.1	3.6	4.5

Horizon	Depth	Sand	Silt	Clay	FT*	LT**
	(cm)	----------(%)----------				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-9	N/A	N/A	N/A	N/A	N/A
A	9-18	17.7	59.5	22.9	SiL	SiL
B/A	18-28	16.5	56.6	26.9	SiL	SiL/SiCL
Bw1	28-51	13.0	52.0	35.0	SiL	SiCL
Bw2	51-93	14.3	50.8	35.0	SiCL	SiCL
BC	93-118	12.8	50.8	36.4	SiCL	SiCL
Cg	118-170+	11.8	46.9	41.2	SiCL	SiCL

FT* Field Texture LT** Laboratory Texture

Table 15. R1~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	0-2	0.00	0.05	N/A
Oa & A	2-3	1.34	0.08	N/A
A	3-8	0.58	0.316	1
BE	8-15	0.37	N/A	1.2
Bw	15-46	3.69	N/A	1.6
Bgx1	46-68	14.61	N/A	1.8
Bgx2	68-125	7.98	N/A	1.9
C	125-150+	1.01	N/A	1.9

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		(%)				
Oi1	0-2	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	N/A	N/A	N/A	N/A	N/A
A	3-8	1.1	0.9	0.8	1.7	7.5
BE	8-15	0.6	0.6	0.8	0.8	2.8
Bw	15-46	3.3	2.5	2.8	5.7	11.9
Bgx1	46-68	6.6	4.6	3.6	3.9	7.0
Bgx2	68-125	3.3	3.2	3.1	3.2	6.4
C	125-150+	0.3	0.6	0.6	0.7	2.7

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		(%)				
Oi1	0-2	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	N/A	N/A	N/A	N/A	N/A
A	3-8	12.0	66.9	21.1	SiL	SiL
BE	8-15	11.3	58.1	30.6	SiL	SiCL
Bw	15-46	26.1	49.2	24.8	CL	L/SiL
Bgx1	46-68	25.5	58.6	15.9	CL	SiL
Bgx2	68-125	19.3	61.2	19.6	SiL	SiL
C	125-150+	5.2	59.1	35.7	SiL	SiCL

FT* Field Texture LT** Laboratory Texture

Table 16. R2~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	0-1	0.00	0.06	N/A
Oi2	1-3	0.00	0.09	N/A
A	3-10	3.35	1.11	1.1
AB	10-16	5.62	1.44	1.1
Bw1	16-30	6.44	N/A	1.5
Bw2	30-44	1.63	N/A	1.6
Bw3	44-70	1.32	N/A	1.8
Bx	70-110	5.45	N/A	1.8
C	110-150+	11.20	N/A	1.8

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-10	1.9	2.4	5.1	9.6	10.3
AB	10-16	0.7	2.4	5.6	10.0	10.6
Bw1	16-30	0.8	3.5	7.5	11.3	11.6
Bw2	30-44	0.9	3.5	8.0	11.5	11.7
Bw3	44-70	1.5	2.8	6.1	10.5	11.6
Bx	70-110	1.4	3.0	5.2	6.4	8.8
C	110-150+	2.5	1.9	1.5	2.1	10.3

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-10	30.6	53.2	16.3	SiL	SiL
AB	10-16	29.7	49.8	20.6	SiL	L/SiL
Bw1	16-30	34.8	43.7	21.4	L	L
Bw2	30-44	35.6	43.7	20.7	L	L
Bw3	44-70	32.6	42.3	25.2	CL	L
Bx	70-110	25.0	47.2	27.8	CL	CL/L
C	110-150+	18.6	52.5	28.9	L	CL

FT* Field Texture LT** Laboratory Texture

Table 17. R3~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	Bulk Density (clod) (Mg m^{-3})
Oi1	0-1	0.00	0.03	N/A
Oi2	1-4	0.00	0.03	N/A
Oe	4-7	0.00	0.07	N/A
Oa	7-42	26.12	0.21	N/A
E	42-55	7.27	N/A	1.9
Bt	55-75	4.67	N/A	1.8
Btx	75-120	1.64	N/A	1.9
Cg	120-150+	1.58	N/A	1.8

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A
Oe	4-7	N/A	N/A	N/A	N/A	N/A
Oa	7-42	N/A	N/A	N/A	N/A	N/A
E	42-55	1.5	5.6	21.7	15.4	6.8
Bt	55-75	1.0	4.0	14.9	12.7	5.4
Btx	75-120	1.0	2.9	9.4	9.3	4.7
Cg	120-150+	1.1	1.7	6.8	7.3	3.4

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A
Oe	4-7	N/A	N/A	N/A	N/A	N/A
Oa	7-42	N/A	N/A	N/A	N/A	N/A
E	42-55	51.3	40.4	8.3	SL	L/SL
Bt	55-75	38.3	43.5	18.2	L	L
Btx	75-120	26.1	51.7	22.1	L	SiL
Cg	120-150+	20.3	46.9	32.7	SiCL/CL	CL/SiCL

FT* Field Texture LT** Laboratory Texture

Table 18. R4~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	* Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	1-0	0.00	0.08	N/A
Oi2	0-2	0.00	0.10	N/A
Oe	2-4	N/A	N/A	N/A
Oa/A	4-12	25.82	0.71	N/A
Eg	12-20	5.06	1.29	1.8
Bh	20-30	10.69	N/A	1.6
Bw	30-44	15.51	N/A	1.8
Bx	44-75	7.91	N/A	2.0
BCg	75-100	4.76	N/A	2.0
Cg	100-150+	5.17	N/A	2.0

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	1-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	2.0	8.8	35.0	20.5	5.6
Eg	12-20	1.1	6.4	27.9	20.7	6.2
Bh	20-30	1.9	7.3	22.2	13.4	3.8
Bw	30-44	1.3	6.0	19.9	12.4	3.1
Bx	44-75	3.2	7.6	20.8	16.2	10.0
BCg	75-100	1.3	3.3	9.0	10.0	15.4
Cg	100-150+	0.7	1.4	4.5	6.7	17.4

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi1	1-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	72.0	24.0	4.0	N/A	SL
Eg	12-20	62.1	27.6	10.2	SL	SL
Bh	20-30	48.4	30.2	21.5	L	L
Bw	30-44	42.7	32.4	24.8	SCL	L
Bx	44-75	57.5	31.7	10.8	SL	SL
BCg	75-100	39.2	34.6	26.1	SCL	L/CL
Cg	100-150+	30.6	38.8	30.7	SiCL	CL

FT* Field Texture LT** Laboratory Texture

Table 19. SSC1~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	0-3	0.00	**0.03	N/A
Oi2	3-6	0.00	**	N/A
Oe	6-8	0.00	0.08	N/A
Oa/A	8-15	0.00	0.63	N/A
A ®	(15-76)	62.72	0.95	N/A
A/E	15-30	42.75	N/A	N/A
BE	30-58	51.55	N/A	N/A
Bw	58-89	39.06	N/A	1.1
Bs ®	(76-89)	40.38	N/A	N/A
Bx	89-125	50.86	N/A	1.5
Cx	125-170+	47.48	N/A	1.9

® indicates that these horizons were only located on the right side of the pit and were not part of the pedon

*both bulk density procedures represent the <2 mm fine earth fraction

**indicates that the Oi1 and Oi2 samples were collected and reported together for that soil's frame bulk density

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		(%)				
Oi1	0-3	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A
Oe	6-8	N/A	N/A	N/A	N/A	N/A
Oa/A	8-15	N/A	N/A	N/A	N/A	N/A
A ®	(15-76)	6.1	4.2	9.4	13.76	12.9
A/E	15-30	3.5	2.6	7.8	13.2	14.4
BE	30-58	6.2	3.7	7.7	12.6	14.8
Bw	58-89	6.2	4.5	7.0	11.5	18.3
Bs ®	(76-89)	14.0	7.0	8.7	13.0	17.3
Bx	89-125	6.2	4.7	7.1	11.6	14.0
Cx	125-170+	12.8	9.5	13.3	17.3	16.8

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		(%)				
Oi1	0-3	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A
Oe	6-8	N/A	N/A	N/A	N/A	N/A
Oa/A	8-15	N/A	N/A	N/A	N/A	N/A
A ®	(15-76)	46.4	44.3	9.4	N/A	L
A/E	15-30	41.8	46.1	12.1	L	L
BE	30-58	45.0	47.6	7.4	SiL	L
Bw	58-89	44.2	45.9	9.9	SiL	L
Bs ®	(76-89)	59.8	38.9	1.3	N/A	SL
Bx	89-125	44.6	46.1	9.3	L	L
Cx	125-170+	69.0	30.3	0.6	SL	SL

FT* Field Texture LT** Laboratory Texture

Table 20. SSC2~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	0-2.5	0.00	0.48	N/A
A	2.5-9	12.82	N/A	N/A
BA	9-30	15.98	N/A	1.0
Bt1	30-41	55.18	N/A	1.3
Bt2	41-61	66.10	N/A	1.3
BC	61-79	76.06	N/A	1.3
C	79-99	86.95	N/A	N/A

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A
A	2.5-9	0.6	1.4	0.6	1.5	8.7
BA	9-30	1.4	1.7	0.9	2.1	8.7
Bt1	30-41	1.6	2.1	1.1	3.4	8.2
Bt2	41-61	1.0	1.4	0.8	2.7	13.1
BC	61-79	0.9	1.0	0.6	1.7	11.4
C	79-99	3.4	2.8	1.6	3.0	10.2

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A
A	2.5-9	13.0	62.6	24.5	SiL	SiL
BA	9-30	15.2	57.3	27.5	SiL	SiCL/SiL
Bt1	30-41	17.0	62.6	20.4	SiL	SiL
Bt2	41-61	19.4	61.9	18.7	SiL	SiL
BC	61-79	15.6	68.0	16.3	SiL	SiL
C	79-99	21.6	70.2	8.2	SiL	SiL

FT* Field Texture LT** Laboratory Texture

Table 21. SSC3~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	* Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	2-0	0.00	0.02	N/A
Oi2	0-2	0.00	0.08	N/A
Oe	2-6	0.00	0.12	N/A
Oa/A	6-11	70.26	0.38	N/A
AB	11-19	65.67	0.87	N/A
Bw1	19-35	29.25	N/A	1.3
Bw2	35-65	35.86	N/A	1.3
Bw3	65-85	45.88	N/A	1.2
BC	85-113	41.96	N/A	1.1
C1	113-138	44.86	N/A	1.5
C2	138-160+	46.79	N/A	N/A

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	N/A	N/A	N/A	N/A	N/A
Oa/A	6-11	N/A	N/A	N/A	N/A	N/A
AB	11-19	6.4	4.2	6.6	14.1	7.3
Bw1	19-35	3.6	3.1	6.2	13.0	7.0
Bw2	35-65	5.0	4.1	6.0	11.3	6.1
Bw3	65-85	11.1	5.9	7.6	13.4	7.3
BC	85-113	11.5	7.4	9.7	16.9	9.5
C1	113-138	9.7	7.1	10.3	18.3	11.9
C2	138-160+	8.0	6.6	9.3	6.5	11.2

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	N/A	N/A	N/A	N/A	N/A
Oa/A	6-11	N/A	N/A	N/A	N/A	N/A
AB	11-19	38.7	46.4	15.0	SiL/L	L
Bw1	19-35	33.2	42.9	23.9	SiL	L
Bw2	35-65	32.6	42.2	25.2	SiL	L
Bw3	65-85	45.3	38.8	15.8	SiL	L
BC	85-113	55.1	35.1	9.7	L	SL
C1	113-138	57.6	35.1	7.3	L	SL
C2	138-160+	52.2	39.3	8.5	L	SL/L

FT* Field Texture LT** Laboratory Texture

Table 22. SSA1~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	Bulk Density (frame) (Mg m^{-3})	Bulk Density (clod) (Mg m^{-3})
Oi	0-2.5	0.00	0.02	N/A
A1 & A2	2.5-13	21.74	0.66	1.3 (A2 only)
BA	13-19	17.67	N/A	1.6
Bt1	19-53	12.73	N/A	1.7
Bt2	53-75	20.39	N/A	1.8
Bt3	75-113	48.78	N/A	1.8
BC	113-137	32.85	N/A	1.9
C	137-160+	24.01	N/A	1.9

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	1.5	0.8	1.9	13.1	11.9
BA	13-19	1.7	7.9	2.5	11.9	10.6
Bt1	19-53	1.3	7.8	2.4	11.2	9.9
Bt2	53-75	3.5	1.5	2.8	11.8	9.2
Bt3	75-113	3.9	2.2	3.4	12.2	8.5
BC	113-137	2.1	2.9	4.1	14.6	9.4
C	137-160+	3.5	2.6	3.9	13.2	8.8

Horizon	Depth (cm)	Sand	Silt	Clay	FT	LT
		----------(%)----------				
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	28.9	54.3	16.8	SiL	SiL
BA	13-19	27.6	51.4	21.0	SiL	SiL
Bt1	19-53	26.1	50.7	23.3	SiCL	SiL/L
Bt2	53-75	28.8	46.2	24.9	CL	L
Bt3	75-113	30.0	45.9	24.1	CL	L
BC	113-137	32.9	45.3	21.8	L	L
C	137-160+	31.9	43.6	24.5	L	L

FT Field Texture LT Laboratory Texture

Table 23. SSA2~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi1	0-1	0.00	**0.03	N/A
Oi2	1-3	0.00	**	N/A
A	3-14	48.16	0.36	N/A
BA	14-34	24.38	0.57	N/A
Bt1	34-60	19.80	N/A	1.6
Bt2	60-107	30.63	N/A	1.7
BC	107-138	13.97	N/A	2.0
C	138-152	13.59	N/A	1.8

*both bulk density procedures represent the <2 mm fine earth fraction

**indicates that the Oi1 and Oi2 samples were collected and reported together for that soil's frame bulk density

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-14	6.0	1.7	0.7	3.2	11.5
BA	14-34	5.6	2.0	1.0	3.0	10.4
Bt1	34-60	4.8	3.1	1.4	2.7	8.5
Bt2	60-107	4.5	2.8	1.2	2.6	7.1
BC	107-138	2.1	1.9	1.0	2.1	6.3
C	138-152	1.8	1.5	0.8	1.9	6.9

Horizon	Depth (cm)	Sand	Silt	Clay	FT	LT
		----------(%)----------				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-14	23.3	63.1	13.6	SiL	SiL
BA	14-34	22.3	58.8	18.9	SiL	SiL
Bt1	34-60	20.5	54.9	24.6	SiCL	SiL
Bt2	60-107	18.6	61.3	20.1	SiL	SiL
BC	107-138	13.7	65.8	20.5	SiL	SiL
C	138-152	13.1	70.1	16.8	SiL	SiL

FT* Field Texture LT** Laboratory Texture

Table 24. SSA3~Physical Data

Horizon	Depth (cm)	Rock Fragments (% by wt.)	*Bulk Density (frame) (Mg m^{-3})	*Bulk Density (clod) (Mg m^{-3})
Oi	N/A	0.00	0.50	N/A
O*	N/A	0.00	N/A	N/A
A1 & A2	0-7	31.74	1.09	N/A
AB	7-12	29.74	0.57	1.0
BA	12-29	14.75	N/A	1.2
Bt	29-65	48.59	N/A	1.4
BC	65-86	55.86	N/A	1.5
C	86-101	65.77	N/A	1.5

*both bulk density procedures represent the <2 mm fine earth fraction

Horizon	Depth (cm)	Sand				
		v. coarse	coarse	medium	Fine	v. fine
		----------(%)----------				
Oi	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	0.6	0.6	0.7	5.1	13.4
AB	7-12	1.4	1.0	0.7	4.6	11.9
BA	12-29	0.7	0.7	0.7	4.3	11.7
Bt	29-65	3.4	2.4	1.3	1.9	6.7
BC	65-86	0.6	0.9	0.5	0.8	8.9
C	86-101	1.5	0.9	0.2	0.5	7.4

Horizon	Depth (cm)	Sand	Silt	Clay	FT*	LT**
		----------(%)----------				
Oi	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	21.1	71.3	7.6	SiL	SiL
AB	7-12	20.3	67.1	12.5	SiL	SiL
BA	12-29	18.9	64.5	16.6	SiL	SiL
Bt	29-65	15.6	62.8	21.7	SiL	SiL
BC	65-86	12.0	66.1	21.9	SiL	SiL
C	86-101	11.3	73.5	15.3	SiL	SiL

FT* Field Texture LT** Laboratory Texture

* this horizon was labeled as an Oa but it clearly was not. More likely an Oi2

APPENDIX C

CHEMICAL DATA FOR EACH PEDON

(Note: All horizon designations are shown how they appeared on the field description sheet).

Table 25. T1~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water mmhos cm^{-1}	----------(%)----------		
Oi1 & Oi2	0-3	3.6(5)	3(10)	0.25(8)	30.1	0.7	0.1
Oe	3-7	3.3(5)	2.6(10)	0.33(8)	43.4	1.4	0.2
Oa	7-15	3.4(3)	2.6(6)	0.38(3)	22.4	0.7	0.1
E	15-25	3.5	3.1	0.13	1.2	tr	tr
EB g	25-34	3.7	3.2	0.10	0.8	tr	tr
Bg1	34-51	4.0	3.5	0.07	0.8	tr	tr
Bg2	51-69	4.3	4.0	0.05	0.4	tr	tr
BC	69-85	4.7	4.3	0.05	0.4	tr	tr
Cg1	85-110	3.7	3.3	0.81	0.5	tr	0.1
Cg2	110-121	3.9	3.6	0.55	0.4	tr	0.1
Cg3	121-160+	4.0	3.7	0.28	0.4	tr	tr

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	3-7	tr	111.7	5.1	1.1	tr	0.5	101.0
Oa	7-15	5.6	99.4	0.4	0.3	tr	0.2	0.1
E	15-25	7.6	18.7	tr	tr	tr	tr	0.0
EB g	25-34	8.2	17.7	tr	tr	tr	0.1	0.0
Bg1	34-51	9.6	18.7	tr	tr	tr	0.1	0.0
Bg2	51-69	7.7	14.1	0.1	0.1	tr	0.1	0.0
BC	69-85	0.5	6.9	0.8	0.8	tr	0.1	1.5
Cg1	85-110	1.1	7.3	1.1	0.8	tr	0.1	0.9
Cg2	110-121	0.6	6.6	1.0	0.6	tr	0.1	1.7
Cg3	121-160+	0.6	5.2	0.9	0.5	tr	0.1	1.5

Horizon	Depth	BS	CEC Activity Ratio	ECEC	Apparent CEC	CEC (NH4OAc)	CEC (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	3-7	5.7	N/A	6.7	N/A	118.8	118.4	100.0
Oa	7-15	0.9	N/A	6.5	N/A	72.5	100.3	13.9
E	15-25	tr	N/A	7.6	N/A	13.4	18.7	tr
EB g	25-34	0.6	2.7	8.3	265.8	12.9	17.8	1.2
Bg1	34-51	0.5	1.3	9.7	128.2	12.2	18.8	1.0
Bg2	51-69	2.1	1.7	7.8	168.7	9.9	14.4	3.8
BC	69-85	19.8	2.3	2.2	233.3	4.6	8.6	77.3
Cg1	85-110	21.5	5.2	3.1	516.5	4.4	9.3	64.5
Cg2	110-121	20.5	2.1	2.3	213.5	4.0	8.3	73.9
Cg3	121-160+	22.4	8.1	2.1	809.2	3.3	6.7	71.4

BS Base Saturation CEC Cation Exchange Capacity ECEC Effective Cation Exchange Capacity

Table 25 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1 & Oi2	0-3	N/A	N/A	N/A
Oe	3-7	4.0	37.6	N/A
Oa	7-15	2.0	28.5	N/A
E	15-25	0.2	1.8	-11.6
EB g	25-34	0.3	3.1	-10.0
Bg1	34-51	0.1	2.0	-0.4
Bg2	51-69	tr	12.1	21.4
BC	69-85	0.1	36.4	31.7
Cg1	85-110	0.1	320.4	-255.7
Cg2	110-121	tr	147.8	-106.5
Cg3	121-160+	tr	146.5	-59.6

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-7	67.4	7064	2565	84	522
Oa	7-15	46.0	16410	2846	13	506
E	15-25	32.6	37315	13409	4	1430
EB g	25-34	28.4	34381	5739	2	1413
Bg1	34-51	51.4	42215	12786	24	2150
Bg2	51-69	54.2	53405	14759	50	2584
BC	69-85	64.6	39545	85159	129	1676
Cg1	85-110	113.4	44687	15359	91	2082
Cg2	110-121	124.8	36471	18659	135	1840
Cg3	121-160+	76.6	37698	20386	146	1854

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1 & Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-7	1067.4	15.0	603	402	1098
Oa	7-15	tr	9.6	423	640	2125
E	15-25	tr	13.2	tr	1014	6139
EB g	25-34	167.8	8.8	tr	1112	7727
Bg1	34-51	270.8	17.8	tr	1602	9364
Bg2	51-69	tr	18.2	tr	1483	9651
BC	69-85	292.2	70.2	398	1486	9076
Cg1	85-110	637.8	24.8	tr	2219	10054
Cg2	110-121	656.6	26.8	168	2198	9340
Cg3	121-160+	580.4	26.8	tr	2043	9159

Table 26. T2~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi	0-2	3.7(5)*	3.1(10)*	0.41(8)*	45.2	1.0	0.1
Oe	2-6	3.4(5)*	2.8(10)*	0.43(6)*	42.2	1.3	0.2
Oa	6-12	3.3(3)*	2.6(6)*	0.40(4)*	26.5	0.7	0.1
EA	12-17	3.5	3.1	0.13	1.1	tr	tr
E	30-41	3.7	3.2	0.07	0.3	tr	tr
Bw	41-61	4.1	3.6	0.04	0.5	tr	tr
BCg	61-79	4.5	3.8	0.03	0.5	tr	tr
C	79-99	4.6	3.9	0.04	0.4	tr	tr
Cg	101-150+	4.5	3.8	0.07	0.7	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-6	tr	107.2	5.2	0.6	0.1	0.6	104.3
Oa	6-12	2.9	104.7	1.7	0.3	0.1	0.2	0.6
EA	12-17	0.1	9.2	tr	tr	tr	tr	0.4
E	30-41	0.7	6.2	tr	tr	tr	tr	0.1
Bw	41-61	3.9	12.5	0.1	tr	tr	0.1	0.0
BCg	61-79	1.5	7.5	0.1	tr	tr	tr	0.0
C	79-99	1.1	7.4	0.1	0.1	tr	tr	0.1
Cg	101-150+	2.2	9.7	0.6	0.5	tr	0.1	0.3

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-6	5.7	N/A	6.5	N/A	112.1	113.7	100.0
Oa	6-12	2.2	N/A	5.2	N/A	67.8	107.0	44.2
EA	12-17	tr	0.7	0.1	68.7	3.5	9.2	tr
E	30-41	tr	0.5	0.7	47.6	2.9	6.2	tr
Bw	41-61	1.6	0.4	4.1	43.6	6.7	12.7	4.9
BCg	61-79	1.3	0.4	1.6	43.6	3.8	7.6	6.2
C	79-99	2.6	0.4	1.3	40.4	3.2	7.5	15.4
Cg	101-150+	11.0	0.4	3.4	41.2	6.4	10.9	35.3

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity
ECEC** Effective Cation Exchange Capacity

Table 26 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi	0-2	N/A	N/A	N/A
Oe	2-6	5.2	61.3	N/A
Oa	6-12	3.2	30.9	N/A
EA	12-17	0.7	6.5	-12.9
E	30-41	0.7	5.7	-6.3
Bw	41-61	0.1	9.4	8.5
BCg	61-79	1.2	6.4	2.6
C	79-99	2.7	0.6	5.4
Cg	101-150+	3.4	9.3	3.0

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	40.8	6525	2755	152	369
Oa	6-12	81.8	9200	3044	44	312
EA	12-17	7.4	12787	1325	5	356
E	30-41	tr	18859	1656	7	567
Bw	41-61	19.0	33641	17469	74	1097
BCg	61-79	13.0	29377	7593	27	1923
C	79-99	27.8	27562	8608	30	1768
Cg	101-150+	48.4	42562	8627	53	2985

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	1190.8	16.6	703	608	1176
Oa	6-12	363.2	14.2	521	580	969
EA	12-17	tr	7.8	121	766	1594
E	30-41	82.2	6.2	106	889	2816
Bw	41-61	196.0	23.2	130	1461	8492
BCg	61-79	254.8	17.0	120	1639	7572
C	79-99	316.8	19.2	177	1844	6192
Cg	101-150+	437.4	22.4	219	1946	8038

Table 27. T3~Chemical Data

Horizon	Depth (cm)	pH (soil : solution) 1: 1 water	1:2 $CaCl_2$	EC 1:2 water mmhos cm^{-1}	Total C (%)	Total N (%)	Total S (%)
Oi1	2-0	4.1	3.6	0.67	48.1	1.0	0.1
Oi2	0-3	3.7	2.9	0.23	45.6	1.4	0.2
Oe	3-9	3.4(5)*	2.5(10)*	0.31(8)*	47.0	1.5	0.2
A	9-18	3.5	3.0	0.16	8.1	0.2	tr
B/A	18-28	4.0	3.5	0.06	3.2	0.1	tr
Bw1	28-51	4.3	3.8	0.06	3.2	0.1	tr
Bw2	51-93	4.5	3.9	0.03	1.1	tr	tr
BC	93-118	4.5	3.9	0.07	0.9	tr	tr
Cg	118-170+	4.5	3.8	0.04	0.7	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth (cm)	Extractable Al (cmolc/Kg)	Acidity	Ca	Mg	Na	K	Ca:Al
Oi1	2-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	3-9	tr	115.1	2.3	1.5	tr	0.4	46.3
A	9-18	15.3	49.6	0.1	0.2	tr	0.1	0.0
B/A	18-28	14.3	40.8	tr	0.1	tr	0.1	0.0
Bw1	28-51	11.7	40.6	tr	tr	tr	0.0	0.0
Bw2	51-93	10.1	18.2	tr	tr	tr	0.1	0.0
BC	93-118	8.6	27.6	tr	tr	tr	0.1	0.0
Cg	118-170+	9.9	20.7	tr	tr	tr	0.2	0.0

Horizon	Depth (cm)	BS* (%)	CEC Activity Ratio	ECEC** ($cmol_c$/Kg)	Apparent CEC ($cmol_c$/Kg clay)	CEC*** (NH4OAc) ($cmol_c$/Kg)	CEC*** (summation) ($cmol_c$/Kg)	BSECEC (%)
Oi1	2-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	3-9	3.5	N/A	4.2	N/A	92.8	119.3	100.0
A	9-18	0.8	1.6	15.7	158.8	36.3	50.0	2.6
B/A	18-28	0.5	1.0	14.5	103.9	28.0	41.0	1.4
Bw1	28-51	tr	0.8	11.7	79.6	27.9	40.6	tr
Bw2	51-93	0.6	0.5	10.2	48.5	16.9	18.3	1.0
BC	93-118	0.4	0.4	8.7	40.9	14.9	27.7	1.2
Cg	118-170+	1.0	0.4	10.1	37.4	15.4	20.9	2.0

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 27 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	2-0	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A
Oe	3-9	3.1	32.7	N/A
A	9-18	0.2	3.4	-8.5
B/A	18-28	0.1	16.7	19.8
Bw1	28-51	0.1	48.8	24.6
Bw2	51-93	0.1	21.4	33.3
BC	93-118	tr	54.4	37.7
Cg	118-170+	0.1	31.0	31.2

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-9	128.4	3181	1664	62	481
A	9-18	28.2	47624	28452	210	1960
B/A	18-28	36.0	29020	41983	265	2561
Bw1	28-51	66.6	66601	41227	308	3503
Bw2	51-93	104.6	77559	51631	1358	4085
BC	93-118	106.0	59870	79583	1062	3410
Cg	118-170+	91.8	69309	27338	2571	4336

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-3	N/A	N/A	N/A	N/A	N/A
Oe	3-9	581.4	13.8	439	266	515
A	9-18	tr	22.4	264	1360	5766
B/A	18-28	tr	33.4	209	1380	7191
Bw1	28-51	tr	41.0	208	1502	9707
Bw2	51-93	362.4	51.8	218	1826	12235
BC	93-118	tr	71.6	249	2301	13176
Cg	118-170+	106.0	32.0	217	2576	15656

Table 28. R1~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi1	0-2	4.0(6)*	3.5(12)*	0.42(8)*	34.2	1.1	0.1
Oa & A	2-3	3.5(3)*	3.0(6)*	0.38	16.5	0.5	0.1
A	3-8	3.3(2)*	3.1(4)*	0.39	10.7	0.4	0.1
BE	8-15	3.5	3.3	0.13	5.5	0.1	0.1
Bw	15-46	4.0	3.5	0.05	4.4	tr	0.1
Bgx1	46-68	4.6	3.7	0.03	5.4	tr	0.1
Bgx2	68-125	4.9	4.0	0.03	5.5	tr	0.1
C	125-150+	4.6	3.9	0.02	0.4	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	9.7	76.8	1.5	0.2	tr	0.1	0.2
A	3-8	9.1	44.1	0.4	0.2	tr	0.2	0.0
BE	8-15	10.3	31.3	0.1	0.1	tr	0.1	0.0
Bw	15-46	4.3	18.2	tr	tr	tr	tr	0.0
Bgx1	46-68	2.8	12.7	0.3	0.3	tr	0.1	0.1
Bgx2	68-125	1.5	9.8	1.6	1.4	tr	0.1	1.1
C	125-150+	0.5	4.4	2.3	2.2	tr	0.1	4.6

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	2.3	N/A	11.5	N/A	50.3	78.6	15.7
A	3-8	1.8	5.5	9.9	551.1	116.2	44.9	8.1
BE	8-15	1.0	1.1	10.6	111.3	34.1	31.6	2.8
Bw	15-46	tr	0.7	4.3	66.4	16.5	18.2	tr
Bgx1	46-68	5.2	0.8	3.4	76.4	12.2	13.4	20.0
Bgx2	68-125	24.0	0.6	4.6	56.0	10.9	12.9	67.4
C	125-150+	51.3	0.2	5.2	24.9	8.9	9.0	90.2

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity
ECEC** Effective Cation Exchange Capacity

Table 28 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-2	N/A	N/A	N/A
Oa & A	2-3	1.1	45.3	N/A
A	3-8	1.0	21.7	-24.8
BE	8-15	0.2	15.4	-1.5
Bw	15-46	tr	12.5	12.6
Bgx1	46-68	0.1	2.2	18.4
Bgx2	68-125	0.4	4.5	24.8
C	125-150+	0.1	1.8	25.8

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-2	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	58.8	51131	18283	45	1681
A	3-8	94.8	46404	13159	16	1489
BE	8-15	167.4	47164	17632	15	1501
Bw	15-46	72.2	57739	49958	56	1766
Bgx1	46-68	88.6	64408	40031	168	2125
Bgx2	68-125	80.6	59370	19283	49	1987
C	125-150+	70.2	78512	11022	106	2291

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-2	N/A	N/A	N/A	N/A	N/A
Oa & A	2-3	336.2	28.8	713	994	7784
A	3-8	346.6	20.2	596	1341	7953
BE	8-15	300.6	40.2	578	1488	9083
Bw	15-46	280.0	81.2	304	1343	9507
Bgx1	46-68	349.6	73.6	258	1664	14140
Bgx2	68-125	617.8	51.2	312	1977	14740
C	125-150+	410.2	25.2	158	2159	20560

Table 29. R2~Chemical Data

Horizon	Depth (cm)	pH (soil : solution) 1: 1 water	1:2 $CaCl_2$	EC 1:2 water mmhos cm^{-1}	Total C	Total N	Total S
					(%)		
Oi1	0-1	4.8(4)*	4.3(8)*	0.69(10)*	48.5	1.6	0.2
Oi2	1-3	4.2(4)*	3.5(8)*	0.45(8)*	43.5	1.6	0.2
A	3-10	3.2	3.1	0.45	6.9	0.3	0.1
AB	10-16	3.3	3.2	0.37	4.4	0.1	tr
Bw1	16-30	4.2	3.7	0.05	1.1	tr	tr
Bw2	30-44	4.4	3.7	0.04	0.8	tr	tr
Bw3	44-70	4.5	3.8	0.06	0.6	tr	tr
Bx	70-110	4.7	3.7	0.02	0.5	tr	tr
C	110-150+	4.8	3.8	0.02	0.7	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth (cm)	Extractable Al	Acidity	Ca	Mg	Na	K	Ca:Al
		(cmolc/Kg)						
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	3-10	8.2	36.1	0.4	0.2	tr	0.1	0.0
AB	10-16	8.4	29.2	0.1	0.1	tr	0.1	0.0
Bw1	16-30	3.5	16.2	tr	tr	tr	tr	0.0
Bw2	30-44	2.6	14.0	0.1	tr	tr	tr	0.0
Bw3	44-70	2.3	12.9	0.1	0.1	tr	0.1	0.0
Bx	70-110	1.6	11.6	0.3	0.2	tr	0.1	0.2
C	110-150+	1.6	11.3	0.6	0.6	tr	0.1	0.4

Horizon	Depth (cm)	BS* (%)	CEC Activity Ratio	ECEC** ($cmol_c$/Kg)	Apparent CEC ($cmol_c$/Kg clay)	CEC*** (NH4OAc) ($cmol_c$/Kg)	CEC (summation) ($cmol_c$/Kg)	BSECEC (%)
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	3-10	1.9	1.5	8.9	145.6	23.7	36.8	7.9
AB	10-16	1.0	0.9	8.7	94.5	19.4	29.5	3.5
Bw1	16-30	tr	0.4	3.5	44.4	9.5	16.2	tr
Bw2	30-44	0.7	0.4	2.7	37.2	7.7	14.1	3.7
Bw3	44-70	2.3	0.3	2.6	28.4	7.2	13.2	11.5
Bx	70-110	4.9	0.3	2.2	27.0	7.5	12.2	27.3
C	110-150+	10.3	0.3	2.9	26.0	7.5	12.6	44.8

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 29 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-1	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A
A	3-10	1.4	11.6	-22.2
AB	10-16	0.6	13.0	-12.6
Bw1	16-30	0.1	9.0	6.9
Bw2	30-44	0.2	10.3	10.2
Bw3	44-70	0.1	16.7	19.9
Bx	70-110	0.2	5.8	20.8
C	110-150+	0.1	2.9	27.8

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-10	28.4	37596	13629	73	1725
AB	10-16	69.6	40351	13316	65	1655
Bw1	16-30	27.6	43243	18917	56	2083
Bw2	30-44	34.8	45051	21119	37	2014
Bw3	44-70	26.6	49494	28520	28	2403
Bx	70-110	38.6	58440	29538	49	2958
C	110-150+	57.6	77411	44759	69	3404

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-10	307.2	26.4	600	1340	7418
AB	10-16	168.2	21.4	478	1422	7299
Bw1	16-30	tr	23.0	263	1273	7382
Bw2	30-44	123.8	23.6	252	1374	6765
Bw3	44-70	134.8	28.4	226	1501	8135
Bx	70-110	tr	34.2	280	1719	12558
C	110-150+	tr	44.8	251	1669	17992

Table 30. R3~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi1	0-1	4.0(4)*	3.7(8)*	0.57(10)*	48.7	1.3	0.2
Oi2	1-4	4.3(4)*	3.7(8)*	0.61(8)*	49.0	1.8	0.2
Oe	4-7	3.6(5)*	3.0(10)*	0.4(8)*	46.5	1.9	0.3
Oa	7-42	3.3(4)*	2.6(8)*	0.47(5)*	41.6	1.7	0.3
E	42-55	3.6	3.1	0.09	0.6	tr	tr
Bw	55-75	3.9	3.4	0.05	1.1	tr	tr
Bx	75-120	4.2	3.6	0.06	0.9	tr	tr
Cg	120-150+	4.3	3.6	0.02	1.8	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	4-7	tr	108.7	6.2	1.2	0.1	0.7	123.4
Oa	7-42	2.0	109.2	1.5	0.6	0.1	0.4	0.7
E	42-55	1.5	6.1	0.0	tr	tr	tr	0.0
Bt	55-75	4.1	11.5	0.1	tr	tr	tr	0.0
Btx	75-120	3.8	10.4	tr	tr	tr	tr	0.0
Cg	120-150+	4.7	13.2	0.1	0.1	tr	0.1	0.0

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	4-7	7.0	N/A	8.2	N/A	137.6	116.9	100.0
Oa	7-42	2.3	N/A	4.6	N/A	98.3	111.8	56.5
E	42-55	tr	0.4	1.5	43.8	3.6	6.1	tr
Bt	55-75	0.9	0.5	4.2	47.4	8.6	11.6	2.4
Btx	75-120	tr	0.3	3.8	34.7	7.7	10.4	tr
Cg	120-150+	2.3	0.3	5.0	34.9	11.4	13.3	6.0

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 30 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-1	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A
Oe	4-7	8.5	84.0	N/A
Oa	7-42	5.9	55.7	N/A
E	42-55	0.5	4.6	-10.0
Bt	55-75	0.2	4.3	-3.0
Btx	75-120	0.5	7.2	3.5
Cg	120-150+	0.1	5.0	7.6

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A
Oe	4-7	97.4	3638	1952	134	355
Oa	7-42	137.2	7870	4786	55	427
E	42-55	91.8	18029	2111	5	464
Bt	55-75	89.8	45008	16121	6	1790
Btx	75-120	42.2	53850	16672	28	2355
Cg	120-150+	56.2	68400	16816	14	2732

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-4	N/A	N/A	N/A	N/A	N/A
Oe	4-7	1332.6	12.8	790	330	598
Oa	7-42	332.2	19.8	733	632	1085
E	42-55	tr	tr	127	697	2367
Bt	55-75	tr	21.6	235	1169	9860
Btx	75-120	tr	29.0	230	1464	13043
Cg	120-150+	tr	35.8	271	1854	20204

Table 31. R4~Chemical Data

Horizon	Depth (cm)	pH (soil : solution) 1: 1 water	1:2 $CaCl_2$	EC 1:2 water mmhos cm^{-1}	Total C	Total N	Total S
					----------(%)----------		
Oi1	1-0	3.8(6)*	3.3(12)*	0.41(10)*	48.3	1.0	0.2
Oi2	0-2	4.0(4)*	3.4(8)*	0.56(8)*	49.3	1.4	0.2
Oe	2-4	N/A	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	3.7	2.7	0.28	6.0	0.1	tr
Eg	12-20	3.6	3.1	0.09	0.8	tr	tr
Bh	20-30	3.6	3.1	0.05	1.7	tr	tr
Bw	30-44	4.1	3.6	0.12	1.0	tr	tr
Bx	44-75	4.4	3.8	0.03	0.3	tr	tr
BCg	75-100	4.6	3.8	0.03	0.3	tr	tr
Cg	100-150+	4.6	3.8	0.03	0.3	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth (cm)	Extractable Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	1-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	1.2	22.5	0.3	0.2	0.1	0.2	0.3
Eg	12-20	1.8	8.2	tr	tr	tr	tr	0.0
Bh	20-30	6.8	21.4	0.1	0.1	tr	0.1	0.0
Bw	30-44	10.5	28.9	0.1	0.1	tr	0.1	0.0
Bx	44-75	1.7	5.0	tr	tr	tr	tr	0.0
BCg	75-100	2.4	6.8	0.5	0.4	tr	0.1	0.2
Cg	100-150+	2.0	6.0	0.8	0.6	tr	0.1	0.4

Horizon	Depth (cm)	BS* (%)	CEC Activity Ratio	ECEC** (cmolc/Kg)	Apparent CEC (cmolc/Kg clay)	CEC*** (NH4OAc) ----------($cmol_c$/Kg)--------	CEC*** (summation)	BSECEC (%)
Oi1	1-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	3.4	3.0	2.0	299.4	12.0	23.3	40.0
Eg	12-20	tr	0.5	1.8	53.2	5.4	8.2	tr
Bh	20-30	1.4	0.6	7.1	61.7	13.2	21.7	4.2
Bw	30-44	1.0	0.8	10.8	77.1	19.1	29.2	2.8
Bx	44-75	tr	0.3	1.7	34.7	3.7	5.0	tr
BCg	75-100	12.8	0.2	3.4	22.0	5.7	7.8	29.4
Cg	100-150+	20.0	0.2	3.5	20.5	6.3	7.5	42.9

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 31 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	1-0	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A
Oa/A	4-12	1.0	16.6	-27.3
Eg	12-20	0.6	3.6	-8.8
Bh	20-30	0.2	tr	12.2
Bw	30-44	0.6	10.7	-5.6
Bx	44-75	0.3	tr	0.4
BCg	75-100	0.7	6.0	5.5
Cg	100-150+	0.6	5.3	9.1

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	1-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	26.8	9917	1719	16	283
Eg	12-20	25.8	18543	4065	11	903
Bh	20-30	54.2	42192	22534	34	3228
Bw	30-44	36.4	38122	18397	33	2404
Bx	44-75	29.6	32922	8220	27	1460
BCg	75-100	43.6	62705	7380	18	2693
Cg	100-150+	66.2	68892	7513	25	2830

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	1-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-4	N/A	N/A	N/A	N/A	N/A
Oa/A	4-12	tr	7.8	157	524	844
Eg	12-20	tr	5.2	64	596	2910
Bh	20-30	226.0	25.8	198	1634	9120
Bw	30-44	26.8	20.0	219	1112	7730
Bx	44-75	tr	12.8	95	1201	7140
BCg	75-100	tr	18.0	122	689	12498
Cg	100-150+	149.0	20.0	109	1237	14432

Table 32. SSC1~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water mmhos cm^{-1}	----------(%)----------		
Oi1	0-3	3.5(8)*	3.3(16)*	0.80(10)*	47.8	0.7	0.1
Oi2	3-6	3.7(5)*	3.1(10)*	0.28(10)*	48.9	1.6	0.1
Oe	6-8	3.4(5)*	2.8(10)*	0.28(8)*	47.9	1.9	0.2
Oa/A	8-15	3.2(3)*	2.7(6)*	0.52(4)*	41.6	2.1	0.2
A ®	(15-76)	3.3	3.0	0.43	7.0	0.2	0.1
A/E	15-30	3.4	3.1	0.21	2.4	0.1	tr
BE	30-58	3.7	3.3	0.12	1.6	tr	tr
Bw	58-89	4.1	3.8	0.08	3.5	0.1	tr
Bs ®	(76-89)	4.0	3.6	0.02	2.5	tr	tr
Bx	89-125	4.6	4.4	0.07	1.5	tr	tr
Cx	125-170+	4.6	4.3	0.02	1.1	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)
® indicates that these horizons were only located on the right side of the pit and were not part of the pedon

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	6-8	tr	110.6	11.0	1.1	0.1	0.6	219.5
Oa/A	8-15	6.8	105.7	1.1	0.7	0.2	0.9	0.2
A ®	(15-76)	4.4	27.3	0.4	0.1	0.1	0.1	0.1
A/E	15-30	6.5	21.9	0.1	0.1	tr	tr	0.0
BE	30-58	5.8	18.6	0.1	tr	tr	tr	0.0
Bw	58-89	7.9	38.8	tr	tr	tr	tr	0.0
Bs ®	(76-89)	0.9	12.1	tr	tr	tr	tr	0.1
Bx	89-125	7.8	33.1	0.1	tr	tr	tr	0.0
Cx	125-170+	0.8	9.8	tr	tr	tr	tr	0.1

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	0-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	6-8	10.4	N/A	12.8	N/A	186.0	123.4	100.0
Oa/A	8-15	2.7	N/A	9.7	N/A	95.8	108.6	29.9
A ®	(15-76)	2.7	2.7	5.1	265.8	24.9	28.0	13.7
A/E	15-30	2.5	1.3	6.7	128.2	15.6	22.1	3.0
BE	30-58	0.9	1.7	5.9	168.7	12.4	18.7	1.7
Bw	58-89	tr	2.3	7.9	233.3	23.1	38.8	tr
Bs ®	(76-89)	tr	5.2	0.9	516.5	6.9	12.1	tr
Bx	89-125	0.3	2.1	7.9	213.5	19.9	33.2	1.3
Cx	125-170+	tr	8.1	0.8	809.2	5.2	9.8	tr

BS* Base Saturation via CEC by summation ECEC** Effective Cation Exchange Capacity CEC*** Cation Exchange Capacity

Table 32 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-3	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A
Oe	6-8	5.9	34.3	N/A
Oa/A	8-15	3.5	34.1	N/A
A ®	(15-76)	0.9	14.3	-25.5
A/E	15-30	0.2	4.8	-8.6
BE	30-58	0.1	0.6	-7.2
Bw	58-89	0.5	2.7	17.5
Bs ®	(76-89)	0.8	1.3	5.8
Bx	89-125	0.1	1.5	11.3
Cx	125-170+	1.3	1.5	4.0

® indicates that these horizons were only located on the right side of the pit and were not part of the pedon

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-3	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A
Oe	6-8	50.4	2457	1235	179	285
Oa/A	8-15	92.2	9225	5150	59	354
A ®	(15-76)	37.8	28265	21096	35	822
A/E	15-30	38.6	33181	26670	38	978
BE	30-58	34.8	39575	29834	37	1294
Bw	58-89	68.2	42434	31335	81	1689
Bs ®	(76-89)	95.0	54692	35892	416	2425
Bx	89-125	58.0	48762	38852	51	1736
Cx	125-170+	78.8	49994	31089	428	1542

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-3	N/A	N/A	N/A	N/A	N/A
Oi2	3-6	N/A	N/A	N/A	N/A	N/A
Oe	6-8	2274.6	19.4	613	402	649
Oa/A	8-15	635.8	29.2	394	878	1446
A ®	(15-76)	tr	25.8	249	1060	5305
A/E	15-30	tr	30.0	tr	1007	4794
BE	30-58	tr	31.8	73	996	6412
Bw	58-89	tr	37.4	159	1232	7772
Bs ®	(76-89)	129.8	43.8	159	1520	10393
Bx	89-125	174.6	36.8	tr	1359	9229
Cx	125-170+	114.8	38.2	tr	1288	9513

Table 33. SSC2~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi1	0-2.5	5.4(8)*	5.1(16)*	0.93(12)*	46.5	1.0	0.1
A	2.5-9	4.0	3.6	0.15	3.7	0.2	tr
BA	9-30	4.1	3.7	0.09	2.0	tr	tr
Bt1	30-41	4.3	3.8	0.06	1.3	tr	tr
Bt2	41-61	4.2	3.8	0.06	0.9	tr	tr
BC	61-79	4.2	3.8	0.06	0.7	tr	tr
C	79-99	4.1	3.7	0.09	0.8	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	2.5-9	10.0	28.0	0.4	0.2	tr	0.2	0.0
BA	9-30	8.6	23.5	0.1	0.1	tr	0.1	0.0
Bt1	30-41	6.1	16.2	0.1	tr	tr	0.1	0.0
Bt2	41-61	5.8	14.8	0.1	tr	tr	0.1	0.0
BC	61-79	6.2	13.5	0.1	tr	tr	0.1	0.0
C	79-99	7.1	17.5	0.1	0.1	tr	0.1	0.0

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	2.5-9	2.8	1.0	10.8	95.8	23.4	28.8	7.4
BA	9-30	1.3	0.6	8.9	65.0	17.9	23.8	3.4
Bt1	30-41	1.2	0.6	6.3	59.7	12.2	16.4	3.2
Bt2	41-61	1.3	0.6	6.0	63.9	11.9	15.0	3.3
BC	61-79	2.2	0.7	6.4	72.1	11.8	13.7	3.1
C	79-99	1.7	1.6	7.4	158.1	13.0	17.8	4.1

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 33 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-2.5	N/A	N/A	N/A
A	2.5-9	0.4	0.9	-0.5
BA	9-30	0.2	28.8	8.2
Bt1	30-41	0.2	24.8	7.6
Bt2	41-61	0.2	24.7	6.6
BC	61-79	0.2	18.6	6.3
C	79-99	0.3	22.8	7.0

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A
A	2.5-9	76.4	61648	35407	380	4256
BA	9-30	83.4	64294	34590	453	4974
Bt1	30-41	115.0	62600	31249	251	5023
Bt2	41-61	89.0	69201	39470	305	6525
BC	61-79	132.0	61053	34043	237	4643
C	79-99	85.6	64624	40320	277	6079

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-2.5	N/A	N/A	N/A	N/A	N/A
A	2.5-9	168.6	44.8	394	2615	13484
BA	9-30	tr	45.0	227	2662	14368
Bt1	30-41	245.8	43.8	197	3086	12813
Bt2	41-61	204.0	42.6	209	3086	15736
BC	61-79	180.2	45.8	205	3234	14816
C	79-99	tr	50.2	255	3020	17704

Table 34. SSC3~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water mmhos cm^{-1}	----------(%)----------		
Oi1	2-0	4.8	4.5	0.65	47.2	1.6	0.2
Oi2	0-2	4.9	4.8	0.86	46.4	1.9	0.2
Oe	2-6	3.9(4)*	3.3(8)*	0.57(6)*	45.5	2.0	0.3
Oa/A	6-11	3.3(3)*	2.9(6)*	0.60(4)*	22.9	1.1	0.2
AB	11-19	3.3	2.9	0.45	7.4	0.3	0.1
Bw1	19-35	4.0	3.5	0.10	2.4	0.1	tr
Bw2	35-65	4.3	3.9	0.06	1.4	tr	tr
Bw3	65-85	4.4	4.1	0.04	1.6	tr	tr
BC	85-113	4.5	4.3	0.03	1.1	tr	tr
C1	113-138	4.6	4.3	0.03	1.2	tr	tr
C2	138-160+	4.4	4.2	0.04	2.8	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	2-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-6	tr	103.2	11.4	1.0	0.1	0.7	228.0
Oa/A	6-11	tr	61.4	2.9	0.5	0.1	0.5	58.1
AB	11-19	5.9	32.9	0.7	0.2	tr	0.1	0.1
Bw1	19-35	8.3	25.7	0.1	0.1	tr	0.1	0.0
Bw2	35-65	6.2	21.0	tr	tr	tr	tr	0.0
Bw3	65-85	4.1	14.9	tr	tr	tr	tr	0.0
BC	85-113	1.7	9.8	tr	tr	tr	tr	0.0
C1	113-138	0.8	7.8	tr	tr	tr	tr	0.1
C2	138-160+	0.6	8.8	tr	tr	tr	tr	0.1

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	2-0	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe	2-6	11.3	N/A	13.2	N/A	92.8	116.4	100.0
Oa/A	6-11	6.1	N/A	4.0	N/A	62.4	65.4	100.0
AB	11-19	3.0	1.6	6.9	159.8	23.9	33.9	14.5
Bw1	19-35	1.2	0.8	8.6	82.6	19.8	26.0	3.5
Bw2	35-65	tr	0.5	6.2	51.0	12.8	21.0	tr
Bw3	65-85	tr	0.7	4.1	68.3	10.8	14.9	tr
BC	85-113	tr	0.7	1.7	65.9	6.4	9.8	tr
C1	113-138	tr	0.7	0.8	70.1	5.1	7.8	tr
C2	138-160+	tr	0.9	0.6	93.2	7.9	8.8	tr

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 34 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	2-0	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A
Oe	2-6	9.3	100.8	N/A
Oa/A	6-11	3.1	42.3	N/A
AB	11-19	1.3	12.2	-28.3
Bw1	19-35	0.1	tr	9.1
Bw2	35-65	0.1	63.1	22.0
Bw3	65-85	0.3	94.1	18.4
BC	85-113	0.6	51.2	8.7
C1	113-138	0.7	19.7	6.8
C2	138-160+	1.0	22.3	0.3

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	87.8	3873	1782	428	314
Oa/A	6-11	50.2	25750	11370	105	1076
AB	11-19	48.2	38640	18298	68	1509
Bw1	19-35	50.4	60887	34657	187	2609
Bw2	35-65	56.2	30057	16777	169	1337
Bw3	65-85	112.8	50727	30729	436	2597
BC	85-113	114.4	61435	34836	460	3011
C1	113-138	99.2	56744	31875	521	2600
C2	138-160+	84.8	50777	35403	808	2222

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	2-0	N/A	N/A	N/A	N/A	N/A
Oi2	0-2	N/A	N/A	N/A	N/A	N/A
Oe	2-6	2582.2	31.6	649	286	717
Oa/A	6-11	824.2	19.6	709	1096	5067
AB	11-19	81.0	19.8	531	1471	9022
Bw1	19-35	tr	32.8	251	1447	10826
Bw2	35-65	tr	15.0	126	751	7740
Bw3	65-85	tr	39.0	305	1738	11914
BC	85-113	tr	43.0	346	1797	13144
C1	113-138	tr	41.4	188	1622	12404
C2	138-160+	tr	50.8	206	1528	12618

Table 35. SSA1~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi	0-2.5	6.1(6)	5.7(12)	1.03(8)	30.2	1.2	0.1
A1 & A2	2.5-13	4.3	4.1	0.34	4.7	0.2	tr
BA	13-19	4.4	3.9	0.09	1.4	tr	tr
Bt1	19-53	4.6	3.9	0.05	0.6	tr	tr
Bt2	53-75	4.7	3.9	0.04	0.3	tr	tr
Bt3	75-113	4.8	4.0	0.06	0.3	tr	tr
BC	113-137	4.9	4.1	0.04	0.2	tr	tr
C	137-160+	5.0	4.1	0.03	0.2	tr	tr

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	1.0	19.8	7.1	1.4	tr	0.3	6.8
BA	13-19	3.0	13.6	2.2	0.6	tr	0.1	0.7
Bt1	19-53	4.1	11.3	1.3	0.4	tr	0.1	0.3
Bt2	53-75	2.4	13.3	1.6	0.7	tr	0.1	0.7
Bt3	75-113	3.3	9.8	1.9	0.8	tr	0.1	0.6
BC	113-137	2.9	8.1	3.0	1.2	tr	0.1	1.0
C	137-160+	2.5	7.7	3.9	1.5	tr	0.1	1.5

Horizon	Depth	BS	CEC Activity Ratio	ECEC	Apparent CEC	CEC (NH4OAc)	CEC (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	30.8	1.3	9.8	130.9	22.0	28.6	89.8
BA	13-19	17.6	0.6	5.9	55.2	11.6	16.5	49.2
Bt1	19-53	13.7	0.5	5.9	45.8	10.7	13.1	30.5
Bt2	53-75	15.3	0.4	4.8	35.7	8.9	15.7	50.0
Bt3	75-113	22.2	0.4	6.1	35.1	8.5	12.6	45.9
BC	113-137	34.7	0.4	7.2	43.6	9.5	12.4	59.7
C	137-160+	41.7	0.4	8.0	41.7	10.2	13.2	68.8

BS Base Saturation CEC Cation Exchange Capacity
ECEC Effective Cation Exchange Capacity

Table 35 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi	0-2.5	N/A	N/A	N/A
A1 & A2	2.5-13	0.9	3.5	-11.8
BA	13-19	0.1	tr	9.5
Bt1	19-53	0.1	13.6	20.0
Bt2	53-75	tr	14.6	20.7
Bt3	75-113	tr	16.4	21.2
BC	113-137	tr	11.5	22.7
C	137-160+	0.1	13.7	22.7

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	118.2	41530	21870	977	3283
BA	13-19	82.0	43994	27940	445	3443
Bt1	19-53	96.6	47017	27295	348	3384
Bt2	53-75	72.6	60694	33232	350	4983
Bt3	75-113	74.4	43408	26677	457	3871
BC	113-137	102.6	46727	39840	375	4618
C	137-160+	93.0	48135	28985	527	4706

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi	0-2.5	N/A	N/A	N/A	N/A	N/A
A1 & A2	2.5-13	1781.6	44.8	520	2510	6525
BA	13-19	651.4	45.2	158	2527	6453
Bt1	19-53	441.0	34.4	138	2484	8592
Bt2	53-75	388.2	39.8	tr	2439	6885
Bt3	75-113	555.0	30.4	102	2398	9023
BC	113-137	570.4	57.4	102	2327	10528
C	137-160+	786.0	42.6	90	2431	11630

Table 36. SSA2~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi1	0-1	6.0(8)*	5.6(16)*	1.18(12)*	46.4	0.8	0.1
Oi2	1-3	5.6(6)*	5.1(12)*	0.72(10)*	42.4	1.3	0.1
A	3-14	3.7	3.6	0.48	4.8	0.2	tr
BA	14-34	4.2	4.0	0.10	1.4	tr	tr
Bt1	34-60	4.4	3.8	0.05	0.4	tr	tr
Bt2	60-107	4.5	3.8	0.04	0.3	tr	tr
BC	107-138	4.6	3.7	0.04	0.2	tr	tr
C	138-152	4.6	3.7	0.04	0.2	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	3-14	4.4	22.9	1.1	0.3	tr	0.2	0.2
BA	14-34	3.4	12.4	0.2	0.1	tr	0.1	0.1
Bt1	34-60	4.2	11.2	0.2	0.1	tr	0.1	0.1
Bt2	60-107	5.1	11.1	0.5	0.1	tr	0.1	0.1
BC	107-138	5.7	12.8	0.8	0.6	tr	0.1	0.1
C	138-152	4.8	11.4	1.0	1.2	0.1	0.1	0.2

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi1	0-1	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A	3-14	6.5	1.9	6.0	189.9	25.8	24.5	26.7
BA	14-34	3.1	0.5	3.8	50.2	9.5	12.8	10.5
Bt1	34-60	3.5	0.4	4.6	37.1	9.1	11.6	8.7
Bt2	60-107	5.9	0.5	5.8	49.3	9.9	11.8	12.1
BC	107-138	10.5	0.6	7.2	55.3	11.3	14.3	20.8
C	138-152	17.4	0.7	7.2	67.2	11.3	13.8	33.3

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

Table 36 continued

Horizon	Depth (cm)	Extractable P	Extractable SO_4	SO_4 Adsorption Potential
		(mg/kg)		
Oi1	0-1	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A
A	3-14	1.0	4.8	-6.8
BA	14-34	0.2	27.5	9.9
Bt1	34-60	tr	39.0	20.8
Bt2	60-107	0.1	20.7	25.8
BC	107-138	1.3	7.3	22.6
C	138-152	2.5	2.5	20.7

Horizon	Depth (cm)	Total elemental Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-14	70.8	47748	16768	819	3430
BA	14-34	77.0	43578	22089	534	3434
Bt1	34-60	83.8	45954	24413	321	4243
Bt2	60-107	74.0	52488	29854	268	5668
BC	107-138	76.4	71840	44477	444	8695
C	138-152	79.2	70399	39530	587	7414

Horizon	Depth (cm)	Total elemental Ca	Cu	P	Na	K
		(mg/kg)				
Oi1	0-1	N/A	N/A	N/A	N/A	N/A
Oi2	1-3	N/A	N/A	N/A	N/A	N/A
A	3-14	560.8	28.6	433	4377	7707
BA	14-34	385.6	30.4	167	4221	9158
Bt1	34-60	196.6	33.4	84	4181	12124
Bt2	60-107	166.8	37.0	67	4154	16328
BC	107-138	239.4	46.4	218	4393	20764
C	138-152	291.6	46.8	263	4637	21032

Table 37. SSA3~Chemical Data

Horizon	Depth	pH (soil : solution)		EC	Total C	Total N	Total S
	(cm)	1: 1 water	1:2 $CaCl_2$	1:2 water			
				mmhos cm^{-1}	----------(%)----------		
Oi	N/A	4.9(8)*	4.5(16)*	0.65(10)*	44.9	0.9	0.1
O*	N/A	5.0(5)*	4.5(10)*	0.58(10)*	35.8	1.4	0.2
A1 & A2	0-7	3.7(2)*	3.4(4)*	0.72	12.7	0.6	0.1
AB	7-12	3.7(2)*	3.5(4)*	0.38	5.2	0.2	tr
BA	12-29	3.9	3.7	0.12	1.8	tr	tr
Bt	29-65	4.2	3.8	0.07	1.0	tr	tr
BC	65-86	4.4	3.8	0.05	0.5	tr	tr
C	86-101	4.6	3.8	0.05	0.4	tr	tr

*samples containing high OM content required higher dilutions than 1:1 or 1:2 (ex. 1 soil:4 water)

Horizon	Depth	Extractable						
	(cm)	Al	Acidity	Ca	Mg	Na	K	Ca:Al
		----------(cmolc/Kg)----------						
Oi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	5.3	40.4	3.1	0.7	tr	0.5	0.6
AB	7-12	6.6	27.1	0.7	0.3	tr	0.2	0.1
BA	12-29	5.5	16.3	0.1	0.1	tr	0.1	0.0
Bt	29-65	5.7	14.0	0.1	0.1	0.1	0.1	0.0
BC	65-86	6.4	13.9	0.1	0.3	tr	0.1	0.0
C	86-101	4.8	9.7	0.1	0.9	tr	0.1	0.0

Horizon	Depth	BS*	CEC Activity Ratio	ECEC**	Apparent CEC	CEC*** (NH4OAc)	CEC*** (summation)	BSECEC
	(cm)	(%)		($cmol_c$/Kg)	($cmol_c$/Kg clay)	----------($cmol_c$/Kg)----------		(%)
Oi	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	9.6	2.8	9.6	278.1	21.2	44.7	44.8
AB	7-12	4.2	1.9	7.8	190.7	23.9	28.3	15.4
BA	12-29	1.8	0.7	5.8	69.2	11.5	16.6	5.2
Bt	29-65	2.8	0.5	6.1	49.8	10.8	14.4	6.6
BC	65-86	3.5	0.5	6.9	51.2	11.2	14.4	7.2
C	86-101	10.2	0.6	5.9	62.1	9.5	10.8	18.6

BS* Base Saturation via CEC by summation CEC*** Cation Exchange Capacity

ECEC** Effective Cation Exchange Capacity

* this horizon was labeled as an Oa but it clearly was not. More likely an Oi2

Table 37 continued

Horizon	Depth	Extractable		SO_4
	(cm)	P	SO_4	Adsorption Potential
		(mg/kg)		
Oi	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A
A1 & A2	0-7	4.5	42.7	-39.2
AB	7-12	1.0	18.8	-17.8
BA	12-29	0.2	10.9	-0.5
Bt	29-65	0.3	21.8	7.0
BC	65-86	0.2	17.2	15.8
C	86-101	0.2	14.4	13.1

Horizon	Depth	Total elemental				
	(cm)	Zn	Al	Fe	Mn	Mg
		(mg/kg)				
Oi	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	55.4	40083	21128	162	3031
AB	7-12	60.6	52188	26500	178	3835
BA	12-29	69.2	52094	28418	178	4233
Bt	29-65	78.6	60396	36035	199	5833
BC	65-86	92.8	72773	42244	235	7609
C	86-101	137.0	71752	39731	410	8111

Horizon	Depth	Total elemental				
	(cm)	Ca	Cu	P	Na	K
		(mg/kg)				
Oi	N/A	N/A	N/A	N/A	N/A	N/A
O*	N/A	N/A	N/A	N/A	N/A	N/A
A1 & A2	0-7	1015	23.0	537	4311	9009
AB	7-12	289.8	28.6	337	5010	10583
BA	12-29	371.2	28.0	241	5061	10540
Bt	29-65	209.2	36.6	147	4586	15584
BC	65-86	tr	46.2	186	4429	17788
C	86-101	tr	47.2	147	5113	19352

* this horizon was labeled as an Oa but it clearly was not. More likely an Oi2

APPENDIX D

BIOMASS AND BIOMASS ACCUMULATION DATA

Table 38. Biomass data for each pedon.

Pedon	Landscape position	Living	Dead	1-5"dbh	.1-1" dbh	Seedlings	Shrubs	total
	----------Mg/ha----------							
99-83002	T1	84	0	27	0.00	0	10	111
99-93006	T2	339	0	28	0	0	22	367
00-83002	T3	no data						
99-93002	R1	315	0	0	0	0	0	315
00-83001	R2	169	11	0	0	0	0	180
00-93001	R3	221	3	24	0.00	<1	15	248
00-93003	R4	153	1	30	<1	<1	0	185
99-83001	SSC1	166	0	8	6	0	0	180
99-93005	SSC2	311	4	19	1	<1	0	335
00-93002	SSC3	198	19	50	1	<1	0	267
99-93001	SSA1	557	0	4	1	0	0	562
99-93003	SSA2	516	0	10	<1	<1	0	526
99-93004	SSA3	817	24	358	1	<1	0	1200

Table 39. Individual sawtimber biomass for each species at each site.

T1: 99-83002
Sawtimber biomass

Species	Mg/ha
Hemlock	47.3
Red Maple	11.0
B. Cherry	2.8
R. Spruce	23.4

T2: 99-93006
Sawtimber biomass

Species	Mg/ha
Hemlock	95.6
Red Maple	9.6
Red Spruce	20.3
Spruce	185.6
Y. Birch	28.4

T3: 00-83002
No Data

R1: 99-93002
Sawtimber biomass

Species	Mg/ha
Beech	27.4
Birch	9.2
Cherry	86.3
Cucumber	12.4
R. Maple	179.4

R2: 00-83001
Sawtimber biomass

Species	Mg/ha
Beech	6.0
Cherry	17.2
Red Maple	107.6
F. Magnolia	15.8
Y. Birch	22.0

R3: 00-93001
Sawtimber biomass

Species	Mg/ha
Hemlock	114.8
Cherry	6.0
Red Maple	17.3
S. Maple	5.1
Y. Birch	60.1
R. Spruce	17.6

R4: 00-93003
Sawtimber biomass

Species	Mg/ha
Hemlock	61.0
R. Spruce	77.2
Red Maple	11.1
Y. Birch	3.9

SSC1: 99-83001
Sawtimber biomass

Species	Mg/ha
Beech	6.0
Cherry	17.2
Red Maple	106.2
Magnolia	15.8
Y. Birch	20.5

SSC2: 99-93005
Sawtimber biomass

Species	Mg/ha
Beech	172.6
Cucumber	24.7
R. Oak	8.6
Sweet Birch	11.7
S. Maple	35.6
Y. Poplar	58.0

SSC3: 00-93003
Sawtimber biomass

Species	Mg/ha
Am. Beech	48.9
Cherry	85.8
Red Maple	56.6
Y. Birch	6.2

SSA1: 99-93001
Sawtimber biomass

Species	Mg/ha
Beech	20.4
Y.Poplar	38.3
S. Maple	23.0
Basswood	85.8
Hickory	127.1
White Ash	26.7
R. Oak[1]	

SSA2: 99-93003
Sawtimber biomass

Species	Mg/ha
Beech	28.7
B. Birch	2.0
B. Locust	12.8
Hemlock	0.6
R. Maple	8.0
F. Magnolia	4.7
Red Oak[1]	
S. Beech	31.5
S. Birch	1.8
Service Berry	3.1
S. Maple	4.0
Y. Poplar	93.1

SSA3: 99-93004

Species	Mg/ha
Beech	55.7
Chestnut Oak[1]	
Locust	19.4
R. Oak[1]	
S. Hickory	1.5
Sourwood	2.5
S. Maple	2.6
R. Maple	49.4

[1]Data for Red and Chestnut Oak were omitted due to the overestimated values that were generated. The regression equation (Eq.5) that was used produced elevated values for large trees (DBH as great as 37 inches).

Table 40. Stand ages and biomass accumulation rates for each pedon.

Pedon	Landscape position	Stand age	Biomass accumulation rate
		yr.	Mg ha^{-1} yr^{-1}
99-83002	T1	81	1.37
99-93006	T2	81	4.53
00-83002	T3	82	no data
99-93002	R1	83	3.79
00-83001	R2	90	2.00
00-93001	R3	98	2.53
00-93003	R4	82	2.25
99-83001	SSC1	81	2.22
99-93005	SSC2	97	3.46
00-93002	SSC3	82	3.25

APPENDIX E

CLAY MINERALOGY FOR EACH PEDON

Table 41. Clay mineralogy for each pedon

Pedon	Horizon	LP	Geology	Verm	Kaolinite	Illite	Lepid	Quartz
				----------%----------				
99-83002	Btg1	T1	New River	53	20	4	14	10
99-93006	Bt	T2	Kanawha	16	28	8	22	26
00-83002	Bt1	T3	New River	47	35	A	8	10
99-93002	Bw1	R1	Kanawha	A	41	18	18	23
00-83001	Bw1	R2	Kanawha	52	19	6	5	19
00-93001	Bt	R3	Pottsville	A	35	22	11	29
00-93003	Bh	R4	Kanawha	51	26	6	6	11
99-83001	Bw	SSC1	Kanawha	25	18	7	A	48
99-93005	Bw1	SSC2	Mauch Chunk	41	23	10	A	27
00-93002	Bw1	SSC3	New River	M	56	M	9	35
99-93001	Bt1	SSA1	Mauch Chunk	51	21	8	A	20
99-93003	Bt1	SSA2	Mauch Chunk	35	26	14	A	25
99-93004	Bt	SSA3	Mauch Chunk	39	23	8	A	30

LP = Landscape position
T = Terrace
R = Ridge-top
SSC = Sideslope with cambic horizon
SSA = Sideslope with argillic horizon
A = Absent (or present in trace amounts)
M = Mixed layer
Verm. = Vermiculite
Lepid. = Lepidocrocite